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PLANNING POWER-PLANT WORK[1]

By Walter N. Polakov.[2]

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[1] An address before the Taylor Society at the annual meeting, New York, December 8 and 9, 1916.

[2] Consulting Engineer, New York.

INTRODUCTION

1. In one of his earlier papers, [No. 1401, American Society of Mechanical Engineers] the writer presented the method of setting tasks for firemen as an isolated function of power-plant management. The most precise knowledge of what each man and each machine can do and the most eager desire to attain this aim are of no avail unless the human forces are directed in accordance with the plans consistent in every detail with all available knowledge. The object of this paper is to outline the main functions of an organization capable of planning the power-plant work so as to obtain the predetermined desirable results.

2. The elements of such planning work might be enumerated as follows:

A. Securing the knowledge.
B. Making the knowledge available.
C. Creating conditions which make this knowledge applicable.
D. Observing whether the proper use is made of this knowledge.

Whenever any one of these elemental requirements is not lived up to its ultimate meaning, the plant management is a haphazard undertaking and the automatic penalty varies between 10 and 40 per cent added to the operating cost. In the great majority of power plants the fundamental planning functions do not receive due consideration. The securing of knowledge is left to the resourcefulness of individual employees, often unaided with even most elementary instruments for observations, seldom possessing the necessary time and authority for experimenting and frequently unqualified for scientific research work. As to making the useful knowledge available to the other men, it is considered by the individual employee possessing such valuable knowledge decidedly against his interest, for fear the other fellow will become qualified to take away his job. For the management, unaided by a planning organization, such educational work and training of the employees is an impossibility, principally for the want of time. A fundamental requirement for the proper application of available knowledge and experience is a functional organization of foremanship, a feature totally foreign to the time-honored division of labor in American power plants. Lastly, observations whether the proper use is made of all available knowledge generally, if at all, is made in the final count only; that is, what the actual costs or thermodynamic results were, without due reference to what these results might have been under proper condition and what if these conditions were neglected.

3. In the following, the author* will present the description of a composite case of several power plants, widely varying in size and nature of service, where the application of the principles advocated here were responsible for material reduction of operating costs, increased security of service and marked stabilizing of expenses, besides greatly improving the relations between the management and the employees. The diagrams Figs. 1, 2 and 3 illustrate the trend of progress toward cost reduction—Fig. 1, in a small industrial plant, Fig. 2, medium size public utility central station, and Fig. 3, in a large electrified railway plant. The latter is particularly interesting inasmuch as the results were accomplished without the opportunity of paying a bonus, and are chiefly due to the careful planning of work in the limited sense of the word.

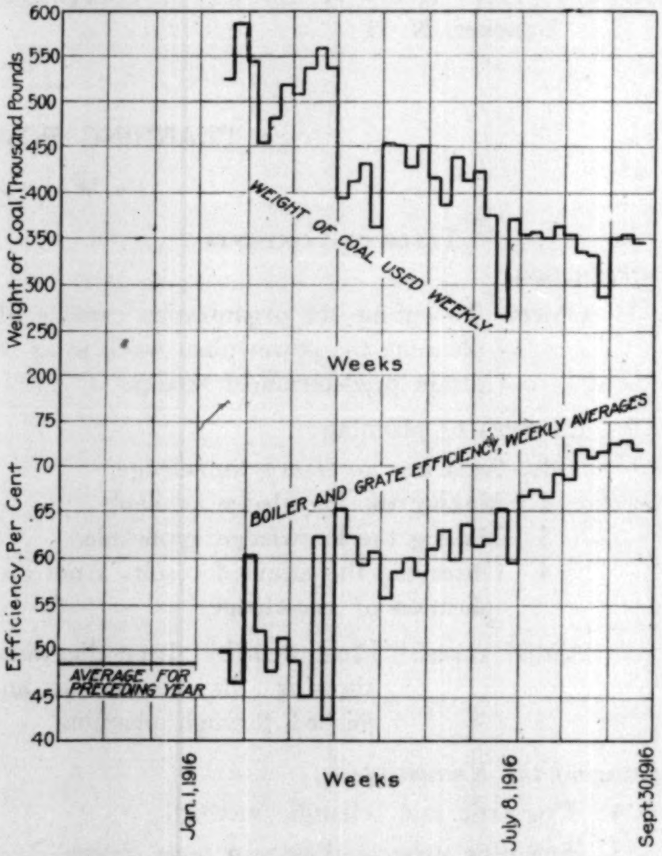

FIG. 1. Cost Reduction in Small Industrial Power Plant.

SECURING THE KNOWLEDGE

4. Broadly speaking, there are two ways of acquiring knowledge. The first and the most ancient method is based on the belief in the authority, either divine or human, and the second, as opposed to the first, is based on the critical analysis of phenomena. Francis Bacon Lord Verulamus laid out the canon of experimental or scientific analysis, whereas Immanuel

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*Acknowledgement is here made of the able assistance rendered to the writer by Mr. Geo. Sheasly and Mr. William Schaller, who fought with him shoulder to shoulder to make a success of these principles.

Kant gave us the most remarkable critiques of our mental processes. Since then the modern or positive science, accepted as the criterion for any positive knowledge, indicates the extent to which the laws representing the relations between causes and results are known. In other words, we can say that we possess scientific knowledge only if we are in a position to precisely foretell the phenomenon in time, space and effect from the study of other phenomena causing and conditioning it. The distinction between the pure and applied science may be drawn where we can or cannot affect at will the conditions causing a desired result. Whereas it would be absurd to create a society to prevent the waste of heat from the earth during the next sun eclipse, it is well worth our while to labor for conservation of human and natural resources lavishly wasted in the power plants.

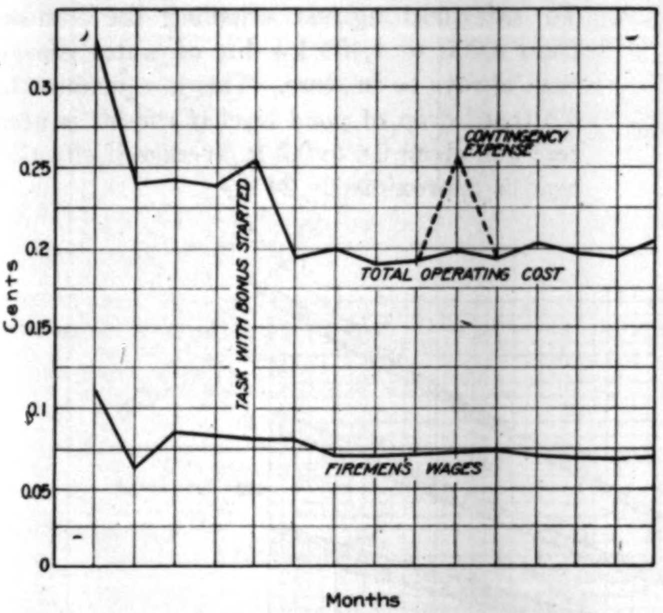


FIG. 2. Cost Reduction in Medium Sized Public Utility Power Plant.

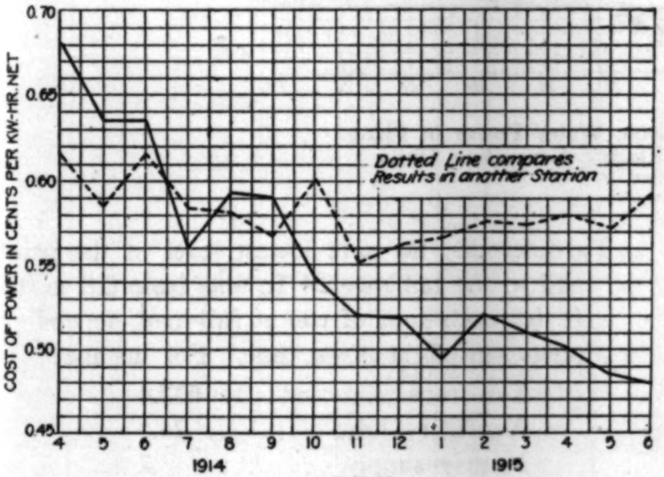


FIG. 3. Cost Reduction in Large Electrical Railway Central Station.

5. Whereas the designers of power-plant machinery may justly be classed as engineers working on scientific basis, inasmuch as exact character of performance of this equipment is accurately predetermined by them before the drawings are sent to the shops, of few managers could the same be said. To predetermine what result can actually be secured from the operation of a plant appears to many as an idle quest. Wherever this has been done, however, the knowledge of what the plant is capable of accomplishing led to efforts to secure the results for which it was built.

The procedure of securing the data showing what a plant can do is, of course, the well-beaten path of scientific analysis and thorough research work. Three distinct steps should be pointed out:

A. Investigation into what conditions result in the highest operating efficiency of each separate unit of equipment.

B. Experimentation leading to the discovery of how these best conditions may be secured and maintained at will.

C. Coördination of thus-found factors in a manner that will show what is the most advantageous interrelation of these conditions and the resulting individual efficiencies from the following aspects: (a) Security of operation; (b) welfare of employees; (c) cost of operation; (d) cost of maintenance; (e) idle overhead expense.

6. This research work is a logical prerequisite to any attempt to manage a plant—not merely "run it" by the grace of the Almighty. When this function of securing the knowledge is vested with the plant's planning department, it becomes its permanent duty to carry out investigations and researches. With every change of condition, be it a new grade of fuel, a different make of supply, a new employee, a change in the character of load or anything else, the planning department starts an investigation to find out exactly how to cope with the circumstances.

7. It would be beyond the writer's task to present here the monograph on methods of power-plant testing, but we deem it entirely in order to make a few remarks concerning the most common fallacies made in this work. The A. S. M. E. and other codes for conducting various power tests, textbooks and treaties written on the subject by professors, etc., totally and deplorably ignore the main point—what the tests are made for.

A. Time and expense of testing made by untrained persons is a pure waste and often serious harm is done for the future by wrong conclusions derived.

B. Tests that are made without keeping complete records of all conditions should not be run at all; only complete and continuous records are useful and dependable.

C. Tests that are not augmented and supplemented by time and motion studies on the men attending the units under test are of limited value inasmuch as the most important factor is thus overlooked—whether under everyday service it is feasible for men to duplicate test conditions.

D. The test data that are not carefully and exhaustively worked out are useless. Again, unless they are analyzed immediately and checked several times by repeat-tests to ascertain that results once obtained can be duplicated at will, they are of no practical value.

E. The object of test or time and motion study being the discovery of the best method, the work is completed satisfactorily only when the findings are reduced to such plain written instruction that the average employee, after reasonable training, demonstration and a little explanation, can live up to them.

As an illustration of the practical results of such research work, we reproduce a standing order showing the method of predetermination of the available water power for one certain plant combining steam and hydro-electric generating units. The diagram, Fig. 4, results from months of studying all necessary information for such predetermination as could be had. More complicated cases of such studies and researches are reproduced in Fig. 5, showing how the theoretically best boiler performance can be ascertained, and the diagram Fig. 6, showing how the various rates for electric power purchased on a contract will affect the unit cost.

STANDING ORDER No. 15

Subject .... Determination of water power available
Written .... December 14, 1912
To go into effect .... January 1, 1913
Superseding .... All previous instructions
Affecting .... Operating Department

Minimum effective head.

A. To safeguard against crippling the system, from 4,000 to 4,400 kw.-hr. of water energy shall always be in store. This is equivalent to 0.8 ft. of drop of pond level if run-off is near zero and about 0.6 to 0.7 ft. average if effective head is approximately 24 ft.

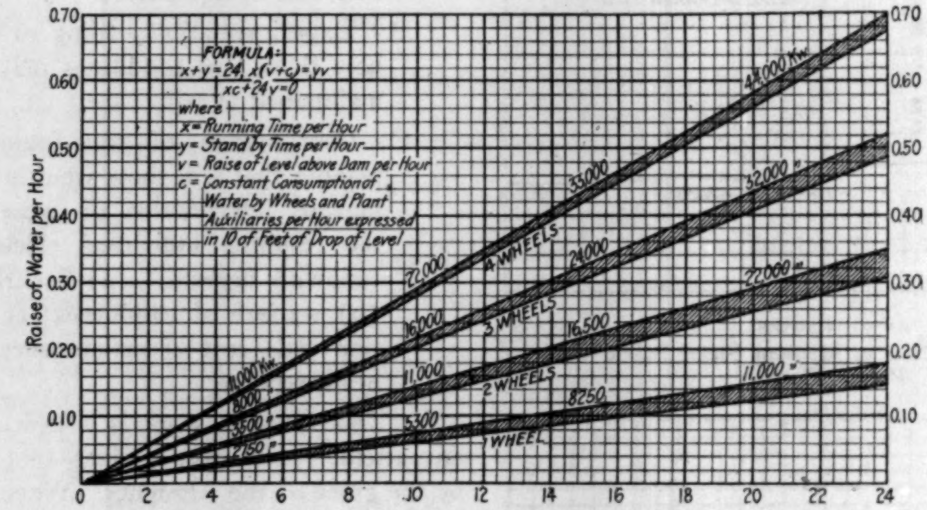


FIG. 4. Predetermination of Available Water Power in Plant Combining Steam and Hydro-Electric Generating Units.

To determine the safe lowest level of the pond add to the tail race 24 ft. and from 0.8 to 0.6 ft. for each hour of run at full load, depending upon run-off at given time. For instance:

Tail race	632.4
Necessary head	24.
Hourly supply	.7
Pond level min.	657.1

Determination of hourly raise of pond

B. Every day, except when run off, the river is equal to or in excess of maximum consumption, the waterwheel generators shall be shut down for several hours for building up the pond. During this period the record of the raise of water level shall be kept every 0.5 hr., and at the end of this period, if the rate of pond raise is uniform, the determination of water raise shall be made as follows: Deduct from the last reading of "head water" before

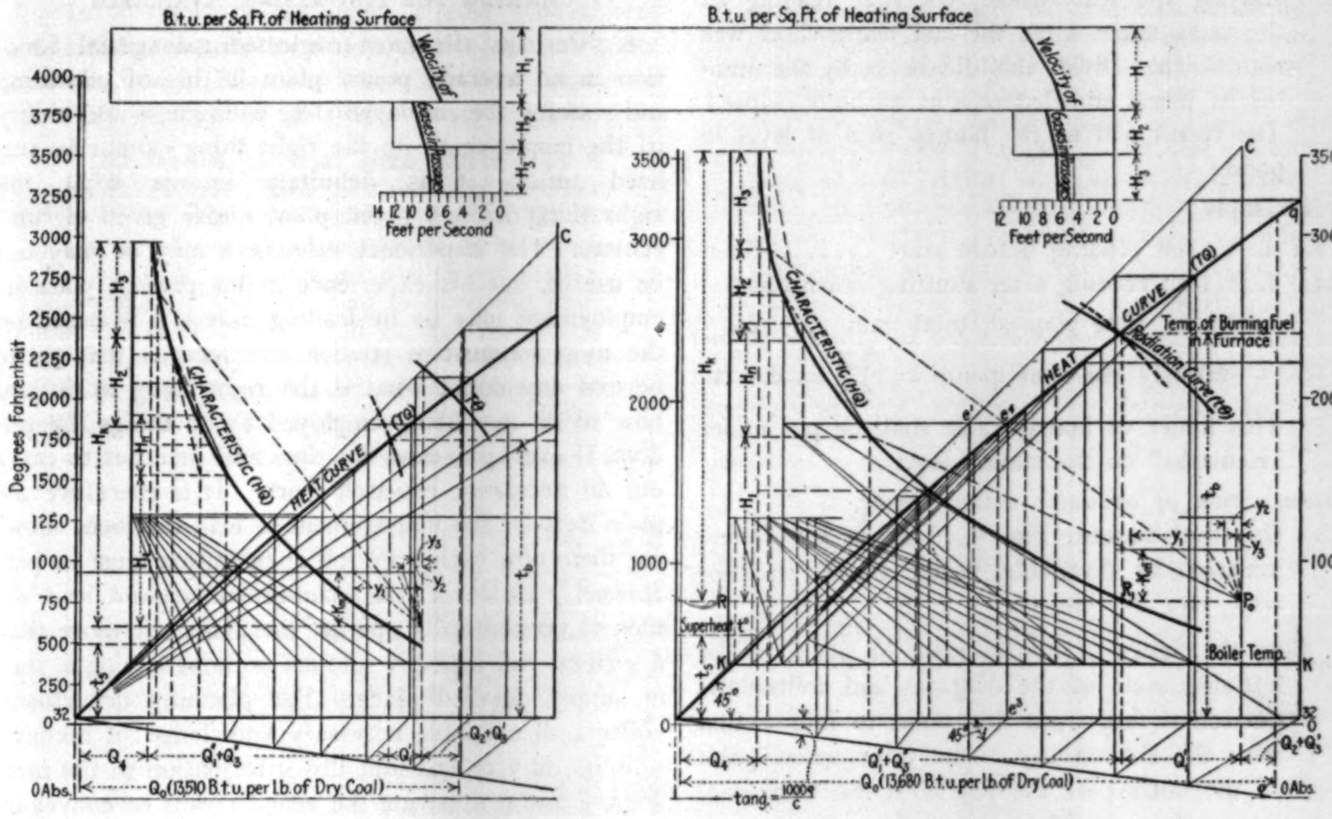


FIG. 5. Diagram showing Theoretically Best Boiler Performance.

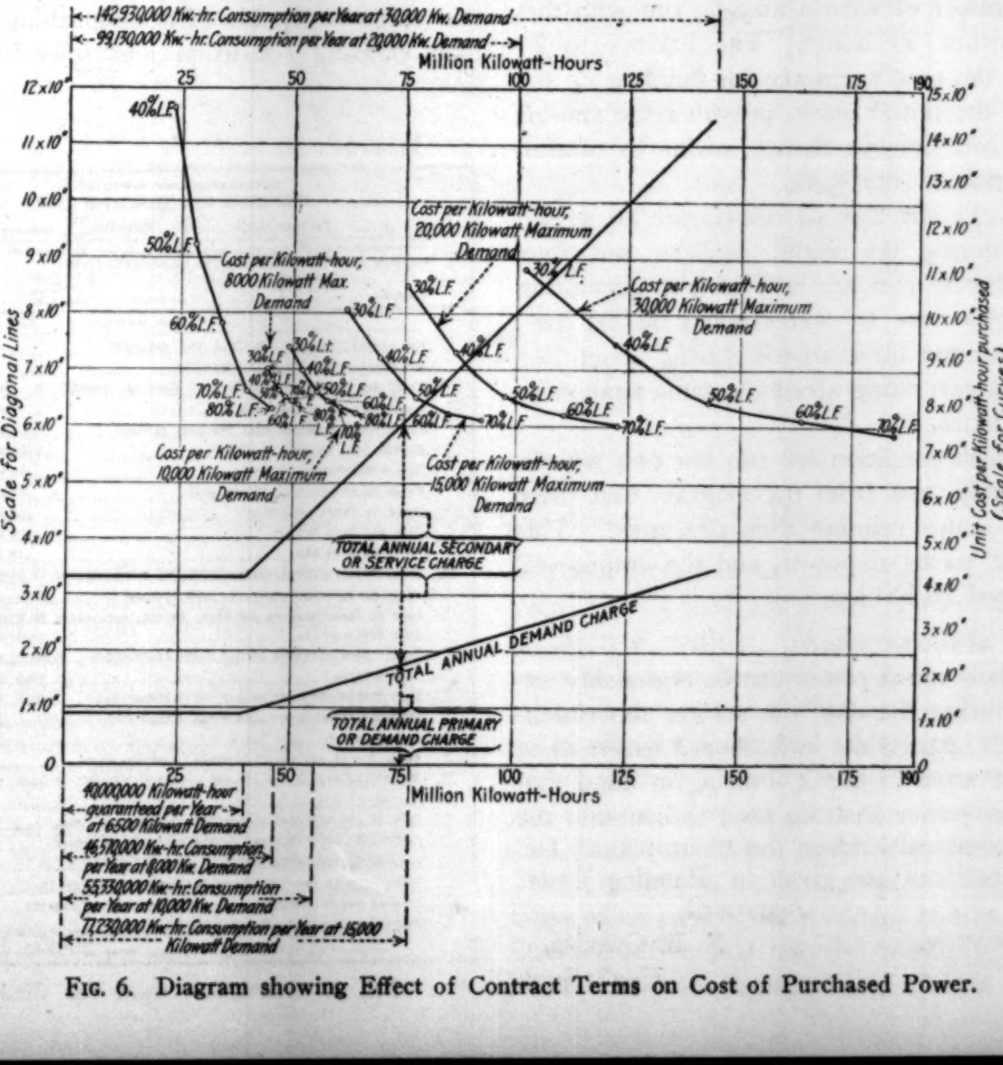


FIG. 6. Diagram showing Effect of Contract Terms on Cost of Purchased Power.

starting the waterwheel, the first reading of the same taken after the last waterwheel was shut down. Divide this difference by the number of hours and decimals of an hour elapsed. The result will be the hourly gain of level in pond.

Example:

5.5 a. m. last reading before start 658.8
12.0 a. m. first reading after shutting down 656.6
5.5 hours' time elapsed, total gain ... 2.2

$$\text{Hourly raise of pond} = \frac{2.2}{5.5} = 0.4 \text{ ft.}$$

This figure of hourly raise shall be put under "Remarks" on the station log.

Determination of available water power.

C. Use the diagram Fig. 4, "Curves for Determination of Available Water Power in kilowatt, etc., as follows:

Find the figure of hourly raise of pond on the left-side scale of the diagram and follow the horizontal line from this point to intersection with the shaded ray. The intersection point of the outline of the ray with the horizontal line is then projected on the scale at the bottom of the diagram and indicates hours and decimals of an hour during which time the given number of wheels may be run with this water within 24 hours. The balance to 24 hours is the time necessary for building up the pond to the initial mark, provided the run-off of the river did not change, owing to rainfall or direction of the wind.

Example: In our case of 0.4 ft. per hr. as observed during the night, we can run four wheels during 13.6 hrs. to 14.3 hrs., generating during this time by water about 32,000 kw.; or we can run three wheels during about 19.5 hrs., thus generating about the same amount or slightly more.

If under such condition we run but two wheels, it is plainly seen from the diagram that there is more water running than consumed. This will be a waste of power, and the output will not exceed 26,500 kw.

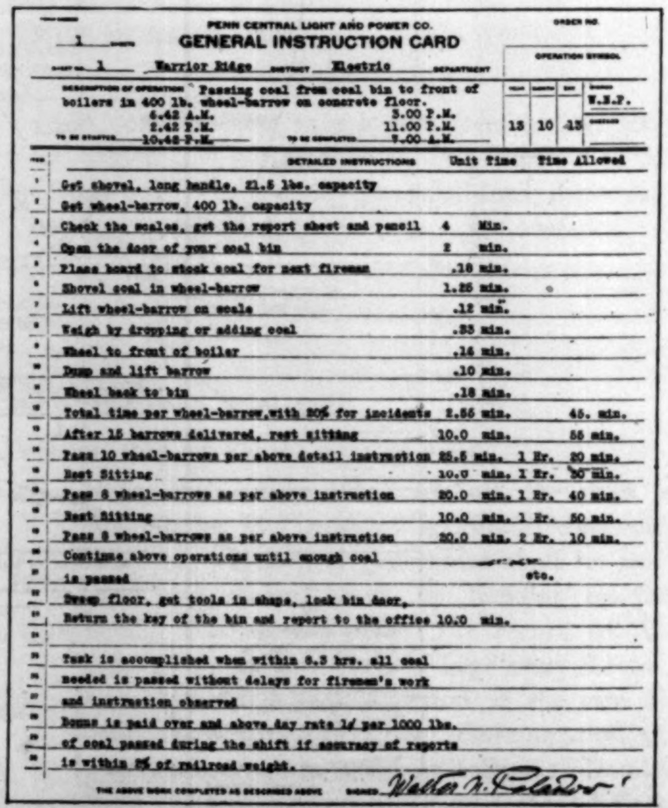
Dispatching of available power.

Knowing how much power can be reasonably expected during the day, the station superintendent shall instruct the switchboard tender as to how and when to use it, bearing in mind that the water power shall be used to maintain the most economical load on the steam plant. Detail instructions are given in Standing Order No. 16.

W. N. Polakov. Approved,
E. B. Greene,
Gen'l. Supt.

Making the Knowledge Available

8. Perhaps the most neglected managerial function in an average power plant is this of educating and training the employee. The willingness and ability of the employee to do the right thing cannot be utilized unless it is definitely known what the right thing is in a given plant under given circumstances. His experience elsewhere may or may not be useful, but his experience in his present place of employment may be misleading unless it is based on the most exhaustive studies and records that prove beyond any doubt what is the right thing to do and how to do it. Being employed to do things, he seldom, if ever, possesses the time and facilities to carry out all necessary research work. It is therefore the plain duty of the management to lead the men, showing them how each little job or operation must be performed. However, the management cannot lead the men to economically operate the plant any more than a general can lead his soldiers without having a staff to supply detailed plans. The planning department collects all available necessary knowledge; it becomes now its duty to transmit this information to the men. Figs. 7 and 8 illustrate the visual means of conveying this verified information to those who perform actual work. It would be utterly wrong, however, to assume that a mere preparation and posting of instruction cards is capable of accomplishing anything more than creating confusion and sometimes dissatisfaction.



PENN CENTRAL LIGHT AND POWER CO.
GENERAL INSTRUCTION CARD
ORDER NO.
1
SHEET NO. 1 Warrior Ridge DISTRICT Electric DEPARTMENT
OPERATION SYMBOL
DESCRIPTION OF OPERATION Passing coal from coal bin to front of boilers in 400 lb. wheel-barrow on concrete floor.
TO BE STARTED 6.42 A.M. 2.42 P.M. 10.42 P.M.
TO BE COMPLETED 3.00 P.M. 11.00 P.M. 7.00 A.M.
13 10 13
W.N.P.

DETAILED INSTRUCTIONS	Unit Time	Time Allowed
Get shovel, long handle, 21.5 lbs. capacity		
Get wheel-barrow, 400 lb. capacity		
Check the scales, get the report sheet and pencil	4 Min.	
Open the door of your coal bin	2 min.	
Place board to stock coal for next fireman	.18 min.	
Shovel coal in wheel-barrow	1.25 min.	
Lift wheel-barrow on scale	.12 min.	
Weigh by dropping or adding coal	.33 min.	
Wheel to front of boiler	.16 min.	
Dump and lift barrow	.10 min.	
Wheel back to bin	.18 min.	
Total time per wheel-barrow, with 20% for incidents	2.55 min.	45. min.
After 15 barrows delivered, rest sitting	10.0 min.	55 min.
Pass 10 wheel-barrows per above detail instruction	25.5 min.	1 Hr. 20 min.
Rest Sitting	10.0 min.	1 Hr. 30 min.
Pass 8 wheel-barrows as per above instruction	20.0 min.	1 Hr. 40 min.
Rest Sitting	10.0 min.	1 Hr. 50 min.
Pass 8 wheel-barrows as per above instruction	20.0 min.	2 Hr. 10 min.
Continue above operations until enough coal		
is passed		etc.
Sweep floor, get tools in shape, lock bin door,		
Return the key of the bin and report to the office	10.0 min.	
Task is accomplished when within 8.3 hrs. all coal		
needed is passed without delays for firemen's work		
and instruction observed		
Bonus is paid over and above day rate 1¢ per 1000 lbs.		
of coal passed during the shift if accuracy of reports		
is within 2% of railroad weight.		

THE ABOVE WORK COMPLETED AS DESCRIBED ABOVE SIGNED Walter N. Polakov

Fig. 7. Instruction Card for Coal Passers.

9. In a public-utility plant a coal passer was started rather hastily on a new method of work per instruction card Fig. 7. The following quotation from a report made on the subject is self-explanatory:

> “180,000 lbs. of coal were handled by 4 men in 24 hrs. Two men working together for 12 hr. each day and passing 45,000 lb. each, could not stand the work; it was too hard. This was because the shovel had a short handle and they had to bend too low; the shovel held only 16 lb. of coal instead of 21.5 lb. causing the workman to bend too many times per ton; the wheelbarrow held only 250 lb., causing too many trips. When the man was given the right kind of shovel and a wheelbarrow holding 400 lb., yet throwing less weight on his arms when lifted loaded, he handled 65,000 lb. in 8 hr. (instead of 45,000 in 12 hr.) and thought the job much easier than before. This man, however, was left to himself before the new way of doing the work formed a habit with him. In a short time he came to us complaining of fatigue and refusing to continue the work. We started to watch him again, and the trouble was clear.
>
> “He did not observe the instruction card. This card ordered rest every so often, for so many minutes, sitting. Instead, the man worked much longer at a stretch, thinking that longer rest afterward would refresh him better, and when resting he spent the time standing and chatting to a fellow worker and not sitting, as prescribed. That was enough to cause fatigue. The rest of the gang of coal passers at Warrior Ridge was finally put on the task in the proper manner, but no complaint has since been heard, and their health and spirits markedly improved.”

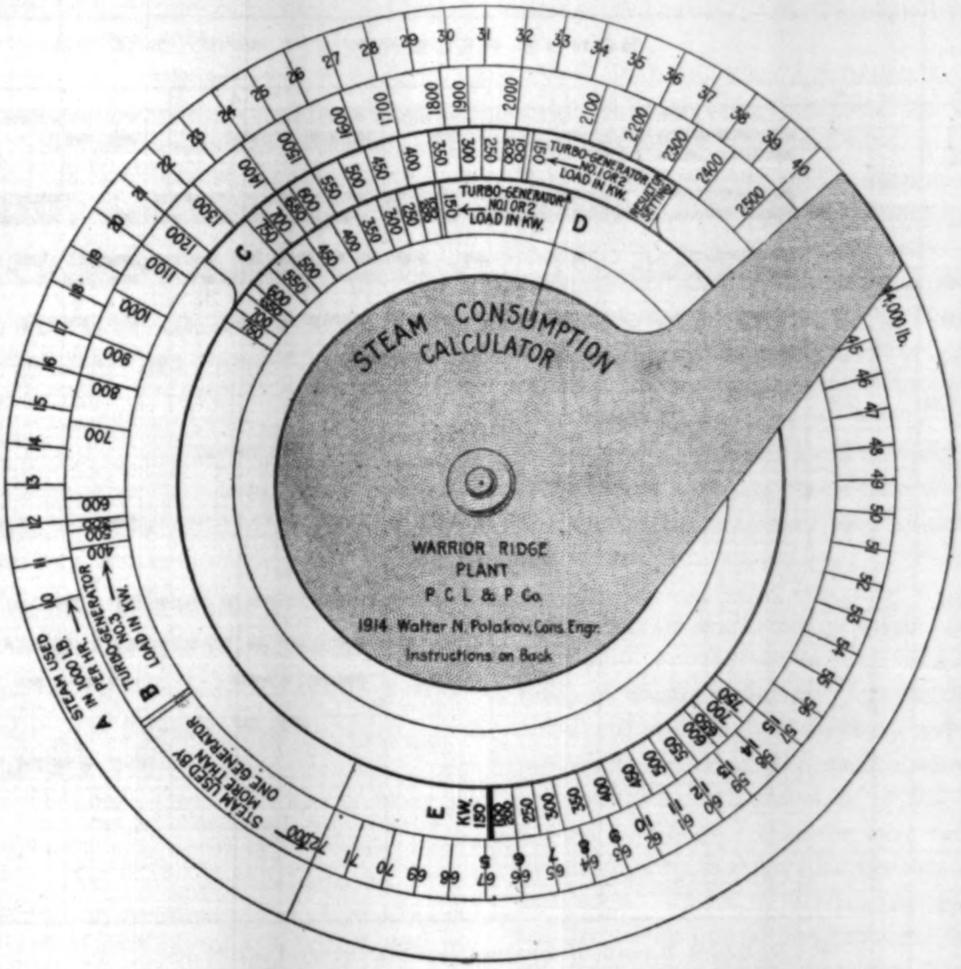

STEAM CONSUMPTION CALCULATOR
WARRIOR RIDGE PLANT
P C L & P Co.
1914 Walter N. Polakov, Cons. Engr.
Instructions on Back
A STEAM USED IN 1000 LB. PER HR.
B TURBO-GENERATOR NO.3 LOAD IN KW.
C
D
E
TURBO-GENERATOR NO.1 OR 2 LOAD IN KW.
STEAM USED BY MORE THAN ONE GENERATOR
KW.
44,000 lb.
72,000

FIG. 8. Slide Rule for Dividing Load Among Steam Turbines.

10. The value of a careful, systematic and prolonged training of the employees cannot be over emphasized. The most difficult part of this work is breaking the old habits. The restraint from the habitual actions often makes the employee nervous even if he is thoroughly convinced of the advantages of the new method. If, however, the new way appears to him as an unreasonable fancy of his superior, who failed to make it clear to him that the change is reasonable and to mutual advantage, the strain on his nerves caused by both suspicion as to the outcome and concentration of mind on unfamiliar actions may take the form of open hostility or concealed sarcasm. The functions of an instructor are therefore at once those of an expert and a tactful human administrator. Demoralization that may be caused by lack of either is serious and far-reaching, and it is commonly

known, that when perfectly good orders issued by the management fail to produce the expected results, the cause can almost invariably be traced to the fact that it was expected that the new order would take place by itself. The old, good saying that the best way to doom a thing to failure is to give it "a fair trial" is always true whenever a capable man is not made reponsible for its success. Whereas these considerations are equally applicable to training workmen in any line of work, the power plant presents a number of special problems in connection with education. Sometimes the most rudimentary knowledge of chemistry and the laws of physics is sufficient, as for firemen, while in other cases more profound insight into the scientific basis of things is essential, as it sometimes is with electricians. Our "engineering letters" form the foundation for subsequent discussions, lectures and other phases of an educational campaign. It would be manifestly erroneous to think that the job of an instructor is a temporary one. It is as permanent as the plant itself, inasmuch as men, supplies, conditions and requirements gradually change; new investigations shall be carried out, and to meet the changing circumstances the management must convey the revised information to the men, constantly making available the gain in knowledge.

11. An idea of what persistent, thorough training can do in forming the habits of securing uniform results may be gained from Figs. 9 and 10. The first table graphically represents the irregularity of work and poor results gradually changing into steady work and uniformly good results attained by firemen under a proper method of training. The second diagram represents the result of well-trained switchboard operators who had to comply with most exacting requirements of a contract under which about one-third of the power consumed by the company is purchased. With fluctuating power consumption from day to day and from hour to hour within a wide margin, with inversely fluctuating proportion of purchased power and without any automatic means of regulation or cutting off, the excess of purchased power, the operators were enabled by training, assisted by a special slide rule, to keep the hourly load factor remarkably uniform, thereby saving the company the severe penalty provided in the contract for excess load factor, at the same time consuming the full amount of contracted power and protecting the company from paying for unconsumed energy below the minimum figure stipulated in the contract.

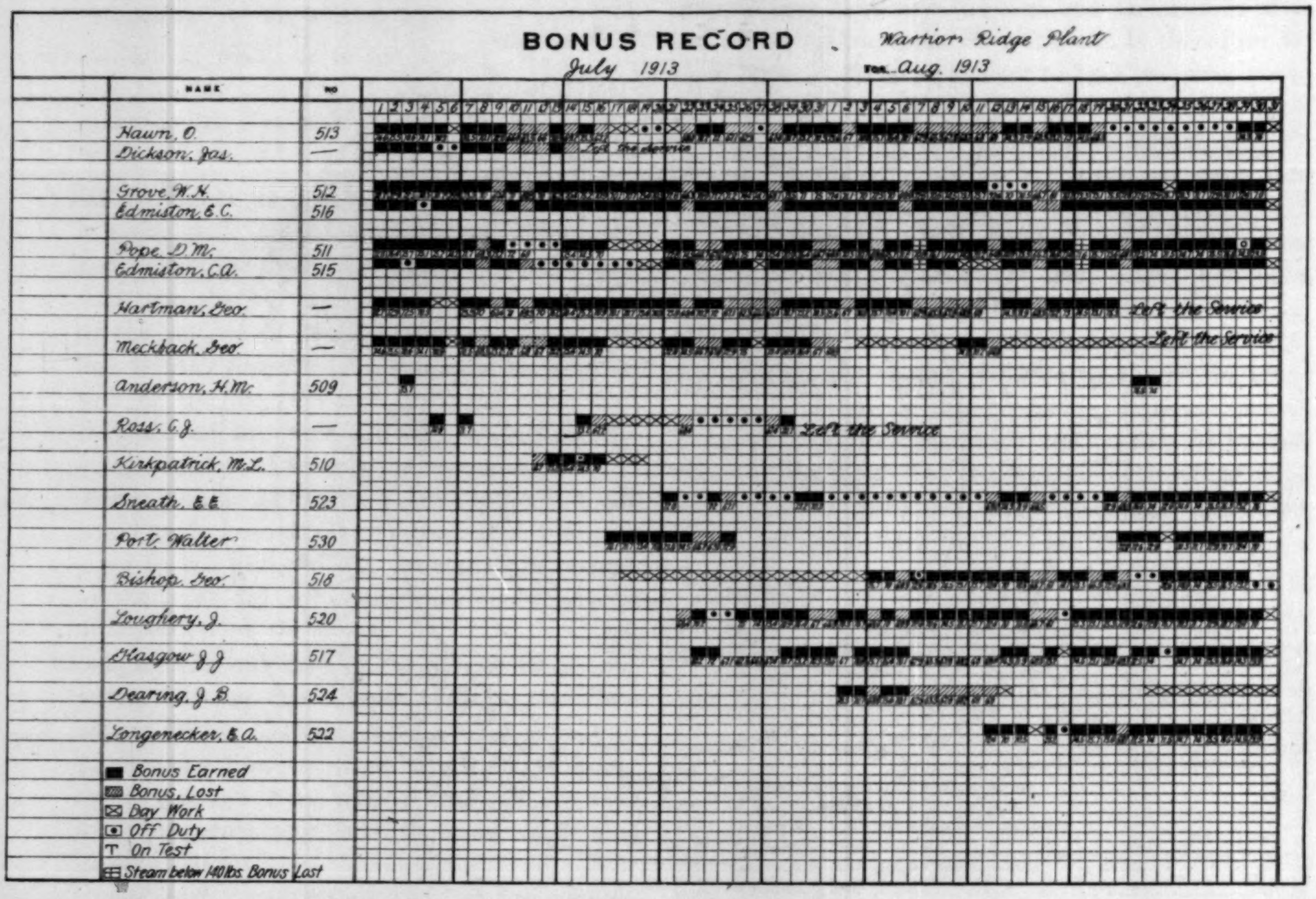


FIG. 9. Bonus Record of Firemen Just Started on Task Work.

12. Whereas the proper selection and careful promotion of the employees is an important function of management, the value of it is often over emphasized,

particularly when the number of available men to select from is limited. The importance of careful and profound training, to the contrary, becomes more pronounced when in addition to the limited labor market an attempt is made to secure uniformly good results from every man on the shift and every shift in the plant. The old-fashioned habit to look for and employ "ready-made" men has had its excuse in Europe, where trade and its tricks were guarded by guilds and conveyed from father to son; it showed little harm in industries where machinery and work were alike in almost every shop. But with the fast development of power-generating equipment and appliances, with widely varying condition and an endless variety of combinations of both, the requirements changed. It is not manual skill nor is it hardened experience brought over from elsewhere, but the ability to acquire new knowledge and to form new habits that is counted as the paramount requirement of every applicant for a power-plant job. It is the duty of the management to mold the proper habits by friendly and persistent training continued day in and day out. No employee should be left to himself until the method known to be the best under a given circumstance becomes a new habit with the man.

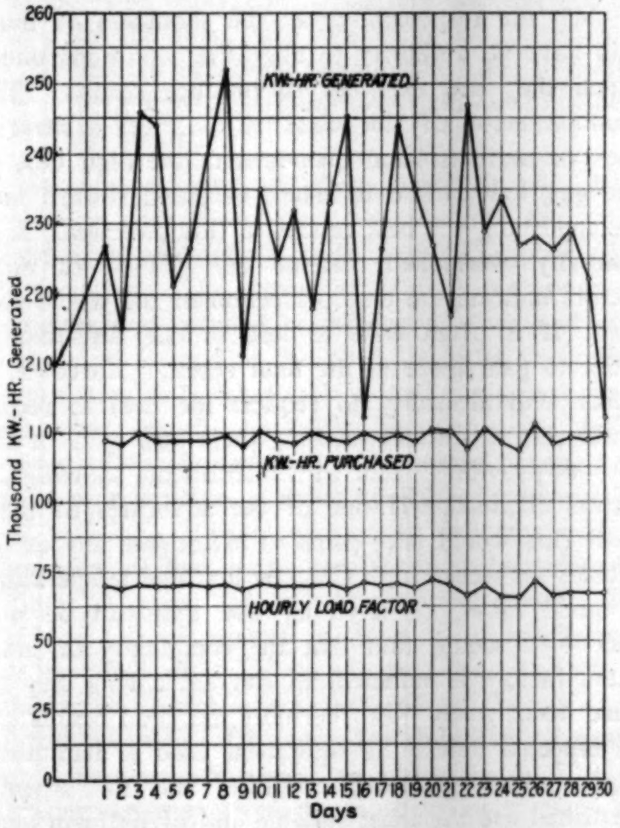


Fig. 10. Record Showing Regulation by Well-Trained Switch-Board Operators of Consumption of Purchased Power in Compliance with Terms of Contract.

While the question of inducement and rewards will be treated elsewhere in this paper, a special case of paying bonus to instructors and bosses is so closely related to this subject of "making knowledge available" that it will be referred to here. The instructors and work-bosses are responsible for teaching men correct methods; therefore their bonus is based not on the economic result accomplished in their departments or by their gangs directly, but indirectly; namely, on the basis of the number of their pupils that succeed in learning how to do the work in the right manner. The boss' reward is thus a fixed bonus for each man in his gang that earns the bonus. This figure is materially increased, in some cases doubled, when all men under his leadership earn their bonuses. This offers a strong incentive to pay the most attention to the training of the most backward ones.

Making the Knowledge Applicable

13. Correct and complete knowledge of what is the right thing to do and what is the right way to do it is of no avail unless the man is taught to perform his duties in the required manner. Now the question is whether he is willing to learn the new way and undergo the strain of unlearning the old habitual one. Like leaving off smoking or walking with toes turned outward, the will-power must be stimulated by an incentive sufficiently attractive to be worth the effort. The reward is a natural inducement, yet regulation wages and a desire to hold the job are rarely, if ever, regarded as anything more than a moral obligation on the part of the employer to provide his employee with the means for existence. Moreover, the increased cost of living, more exacting demands and clearer conception of economic relations constantly work on the mind of the employee, taking periodically the form of demands for an increase of wages.

14. There are two ways of inducing a man to do something—forcing him to it, and making it desirable to him. The advocates of strict military discipline are apt to imagine that the new habits can be forced on the men by fear of dismissal or milder disciplinary measures. This may work so long as the men do not see their way out of the pressure, which usually does not take very long; then the newcomers must be again forced into the regime at great expense of time and energy. Meanwhile an elaborate system of espionage, bossism and pressure must be brought into play if the rule is really to be enforced, otherwise the things are done in the prescribed manner only while men are under surveillance, or more often it only appears so to the casual observers and to the imagination of the advocates of "big-stick" rule.

The obvious advantages of leading and stimulation are:

A. Less effort needed to lead than to push.

B. Voluntary action is performed even when not watched; therefore, the desirable method is followed permanently.

C. The expense of a bonus is covered from the additional saving, whereas the expense of watching and forcing is non-productive.

15. Several methods of stimulating the employee to do better work are known, and unfortunately, the improper ones are used often enough to discredit the correct method in the eyes of those who do not take trouble to study them all. These methods may be roughly classified as follows:

A. Profit-sharing plans.
B. Premium schemes.
C. Rewarding individual efforts.
D. Task with bonus.

The importance of a clear distinction between these methods warrants our discussing them at some length.

Profit sharing is based on the assumption that the employees by their work contribute to the success of the enterprise in securing profits. This would be entirely correct if the employees were given the opportunity to control all functions of mangaement, fix the salaries of directors, direct purchases and sales and have the right of veto in all financial transactions. As long as they are expected, however, to work under the conditions provided by the management, with equipment and material furnished by the management, which in turn disposes of the product, the profit or loss is only slightly influenced by the excellence of the work done by the men. Therefore, if the company earns large dividends, the sharing of it with the employee is but a matter of gift for the purpose of keeping peace with the owners' own conscience, if it is not a plain case of cowardice in anticipation that the men will rebel when they learn how small were their wages compared with the profits derived from their toil. On the other hand, if the dividends were not declared, the workmen would lose their share, although through no fault of their own, since they might have been working as hard as possible, yet blunders in policy and mismanagement ruined the business.

Premium plans as worked out in power plants are very unsatisfactory. The common error of all these attempts is that the final cost of operation is considered as a basis for the award or denial of the premiums. Yet it is perfectly clear that the cost depends not only on the excellence of work, but equally, if not in a much larger degree, upon the method and means of upkeep, cost of fuel and supply and its quality, quantity of output, load factor, use factor, etc. None of these factors is under the control of the power-plant employee. Besides, the extent to which different employees contribute to the accomplishment of economical results is very unequal. While the firemen may affect as much as 50 per cent saving, the switchboard operator cannot influence more than, say, 5 per cent, whereas the floor engineer can save or waste about 1.5 per cent at the most. A Portland cement company demonstrated some few years ago a forceful example of such a muddling blunder and had to drop this plan, as the men did not take kindly to the attempt to deny them their premiums because coal was of poor quality and the mill running light, while they worked their heads off trying to do as good work as they knew how.

The rewarding of individual effort is perhaps the most unscientific scheme of all. These half-baked attempts of inexperienced managers are figured out to shift the responsibility to the shoulders of those who have no authority to alter the conditions under which they are expected to produce results. The common error of this class is to select arbitrarily one or more isolated phenomena, like high CO_2 in flue gas, low carbon in ashes, etc., and reward men accomplishing the best results in this direction. It is generally overlooked that no one or few of these factors indicate the true perfection of the whole process. It is often wise to lose in one direction in order to gain more in the final result. Moreover, it ranks with absurdity to request the men to secure better results without teaching them how to do it and without providing them with instruments showing the results obtained. If one of the advocates of these short cuts would take pains to investigate any of his hobbies—whether high CO_2, or low flue temperature, or good ashes, or anything else that can be produced—he would find that the complexity of influential factors is sufficient to warrant a long step toward detail study. Furthermore, no good results can be expected unless the equipment used is maintained in first-class operating condition and the supplies furnished are the most suitable and of uniform quality.

A glaring example of inconsistency of the individual-reward plan is offered by the method practiced by the efficiency department of the Atchison, Topeka & Santa Fe R. R. Their method is another typical short cut to avoid the long way of careful studies.

Their method is of interest chiefly by way of contrast with the ten years' development in the art. It was recognized that:

A. The actual performance was worse than the possible.
B. Local conditions of various plants call for different standards.

The work of establishing standards of performance was based not on actual experiments, but on average statistical data of the past, reduced by the guessed percentage suspected as waste. Then an allotment was made for each individual plant as to how much fuel should reasonably be consumed there per month.

Similarly, payrolls were revised and certain labor costs were assumed as reasonable. These two records multiplied by constants arbitrarily chosen (6 for fuel and 4 for labor) added together and divided by 10 gives the figure of merit used as a basis for the payment of bonus, the bonus itself being adjusted on a sliding scale. The shortcomings of this crude method are apparent:

A. Men are left to discover for themselves how to secure the results desired by the management.

B. The management, shifting the responsibility to the men, was uncertain as to the exact amount of saving accomplished due to individual efforts, and therefore could not fix a definite bonus.

As opposed to all these methods, or rather muddling with the subject, we advocate the assignment of a well-defined task to each member of an organization. The setting of a task presupposes the complete and detailed knowledge of each and every process performed in the plant, includes the reliable information as to what each unit of equipment can do and what are the conditions producing the desired results. This knowledge, once gained through test and research work, is made available by instructions and training. Results necessarily follow conditions, therefore the task really consists in maintaining conditions as prescribed, not in attaining results, inasmuch as we are assured of these if all requirements are complied with. If we say that the task is to attain certain results, it is a mere colloquial form devoid of true meaning. However, for simplicity of recording it is often convenient to judge by final results whether the men lived up to their instructions and consequently earned their bonus. This is not true in cases where results fall short of predetermination, since it might be caused by a condition beyond the control of the employee, who for no reason of his own neglect or overlook, fails to produce the result expected. To illustrate: Boiler efficiency may materially drop through no fault of the fireman if baffles and arches in the boilers are not maintained, owing to poor planning, lack of material or what not. Steam consumption may increase above what it should be if cool condensing water is not available, by reason of supply trouble. The man may fall behind in removing the ashes in the prescribed time if the locomotive batteries are not properly charged, cleaning schedule disorganized, or from similar causes entirely beyond his control. In such cases it would be manifestly wrong to deny the bonus to the employee who did all that was expected of him, but was unable to produce results through the fault of somebody else or something that could not be prevented by him. Cases of similar nature are treated in detail, an investigation is made to see not what the results were, but whether the conditions prescribed by the instruction card were lived up to. If they were all that was expected from the employee, his bonus is allowed him. This basic principle determines an important characteristic of bonus. As long as the maintenance of a condition is required, the accidental favorable combination of conditions beyond the control of the employee may produce results better than specified, yet it does not bring to the employee any additional reward, as this was not due to his meritorious work. In other words, the bonus remains constant as long as the terms of the instruction card are lived up to, irrespective of whether the results are equal or above a certain predetermined point. In case of results being below a specified mark, the bonus is not paid at all or paid in full, depending on the investigation previously mentioned, but never is the bonus cut or reduced. To represent the relation between the bonus and the result, Fig. 11 shows two curves, one indicating the earning of the fireman with and without bonus, and another, the cost of steam. For any other case, say, switchboard operators, the results may be equally well presented graphically in the same manner as for the firemen.

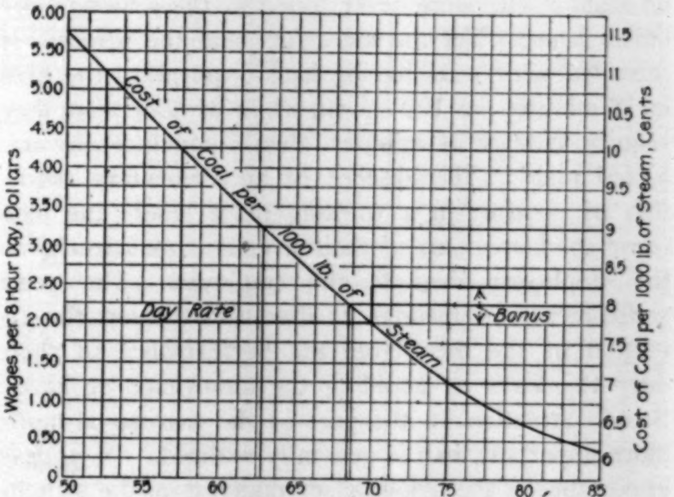


FIG. 11. Diagram Showing Relation Between Bonus of Firemen and Unit Cost of Steam.

16. The knowledge of doing things properly and the strongest desire of working according to best methods is of no avail unless the conditions are such that it is possible to apply this knowledge to everyday toil. It is a well-known fact that in a plant under old-fashioned management the daily performance falls short of the results obtained during a specially arranged test. This is chiefly due to the neglect to plan the work ahead and permanently maintain the conditions prevailing during the test. In importance the elimination of causes producing fatigue shall be ranked first, as in power-plant work neither the best

of machinery nor excellent supplies can produce satisfactory results unless they are handled by men who are not tired, mentally or physically. Our experiments with the firemen show that, other conditions being equal, a fireman on a 12-hour watch is found to be about 4.5 per cent less efficient than the same man on an 8-hour shift. (Considering a man's pay $3 per shift, and one ton of coal per hour at a price of $3, nothing can be gained by 12-hour shifts except an increased risk of accidents; a decided loss will result in cases where wages are lower and coal consumption is either larger or more expensive fuel is used than in our example.)

One familiar with the common layout of a power-plant cannot over emphasize the importance of the hygienic conditions to enable the men to live up to their task day in and day out. While engine rooms not infrequently offer very pleasant and sanitary surroundings, boiler houses, the most important part of any plant, are often so built as to make them unbearably cold in winter and uncomfortably hot during the summer. Good lighting is an unusual luxury, so that after looking into the furnace the fireman cannot read the gages or examine anything around the boiler. Good drinking water is rarely provided, and restful seats with backs (seats without backs are as bad as no seats at all) were never found by the writer in any boiler house. Yet the mere fact that the firemen, if provided with seats having backs, can clean the fires in 18 minutes per 100 sq. ft., while without them they require at least 24 minutes, should convince any unbiased mind. The absence of an elementary condition of comfort in a working place where the men spend the better part of their lives is more harmful to the employers than to the employee. The petty annoyances and feelings of discomfort divert the attention of the men from the performance of their duty to means of avoiding the annoyance or harm. Steady attention on the part of the fireman is much more important than is generally realized. Of no less importance is the hygienic surrounding on the switchboard gallery. Flickering light from low frequency circuits, glare on the instrument glass fronts, cement floors to walk on, inconveniently located telephones, telautographs, too low log-desks, etc., are all excellent means to increase steam consumption per kilowatt-hour and reduce the safety to men, property and service.

It should be at least as much the duty of a planning department to periodically investigate and test the effect of surroundings on the attentiveness and physical fatigue of men as it is its duty to test each coal delivery and supervise the treatment the equipment receives. There are many ways to ascertain the degree and the character of fatigue to which we shall not make reference here for the want of space. Whatever the methods may be, they shall be applied at regular intervals to each and every employee, and their individual health-record cards shall be kept, using some convenient rating to easily watch the decline or gain of vitality of each man. Should the decline be noticed, the measures shall be taken at once to find out the cause. If it is of individual nature, good advice or doctor's services shall be offered; if it affects a group, the harmful condition must be eliminated as rapidly as possible. Little alterations that are usually required to remove harmful conditions are a great deal cheaper (not to say humane) than breaking in and training a new employee, or even temporary substitute. However, complaints of this nature are rare since the properly organized planning department in a power plant usually materially decreases the amount of physical labor to be done for the same results, that is required under the old regime.

17. The maintenance of equipment in first-class operating condition is another imperative task of a planning department. Proper upkeep of power equipment is of far greater influence on output and economy than it is in any other manufacturing department. Neglect to clean the heating surface of boilers, prevent numerous little leaks here and there, etc., seriously affects the cost of power. Careless, sporadic inspection of equipment is much more hazardous in power plants than anywhere else, as it may result not only in crippling of one section of a plant or even cause a shutdown, but is liable to cause more serious disaster. The old saying that a stitch in time saves nine is nowhere more applicable than in a power plant.

In order to secure a possibility of obtaining uniformly good results from proper methods of operation—that is make it possible for the men to live up to their tasks and earn a bonus—the plant's equipment must be maintained in uniformly good condition. To that end, the planning department contributes by studying physical causes affecting economy and safety and determines reasonable periods at which inspections, cleanings and other similar work shall be made. Such schedules are exemplified by the boiler-cleaning record chart, Fig. 12, and electrical inspection card, Fig. 13. The by-effects of work done at regular intervals are: Reduced time the equipment is idle, reduced number of maintenance men needed, lower repair and maintenance cost, and above all, the operating men (who may be poor mechanics) are not dividing their attention between operating functions and mechanical work, but consistently live up to their tasks. The general procedure of this work is simple. The planning department assigns at specified intervals the qualified men to make inspection routes through the plant and report all findings on a card as shown Figs. 14 and 14a. Necessary repairs are authorized

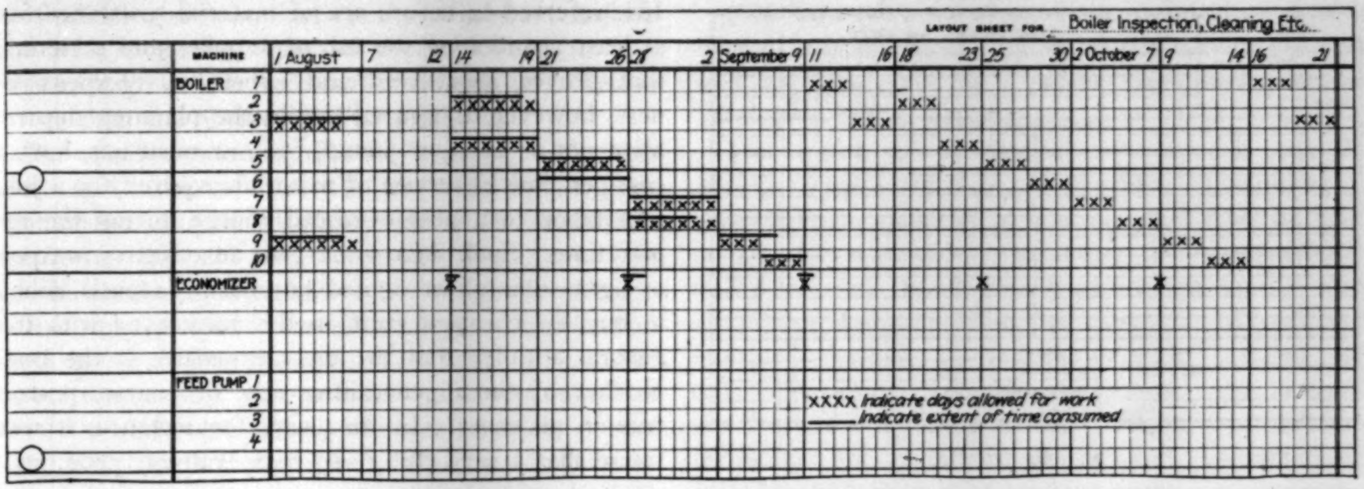
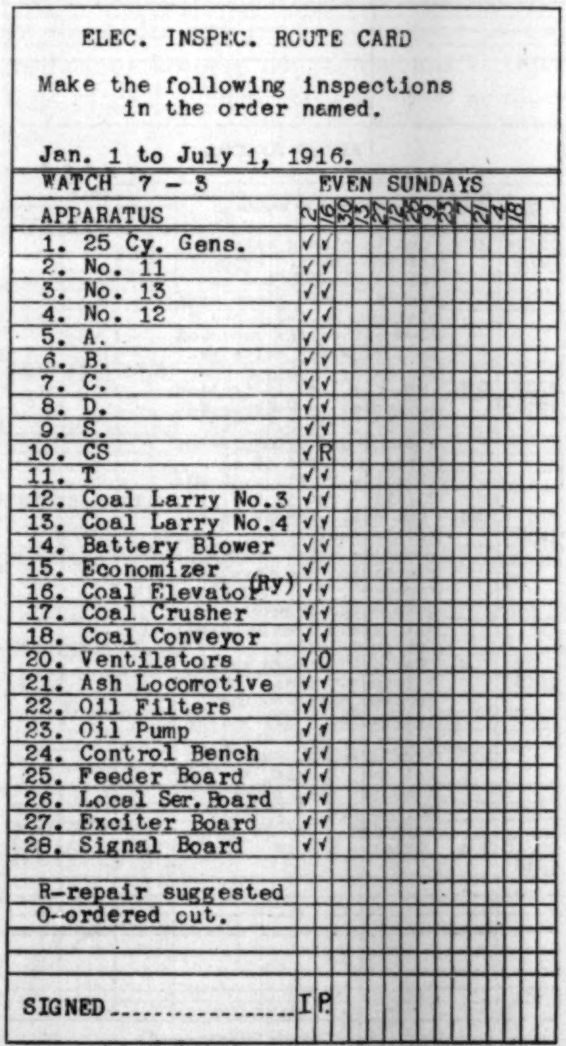


FIG. 12. Boiler Cleaning Schedule.

by the issue of a work order specifying details, Figs. 14b and 14c, and time when it is to be started and finished, so as not to interfere with operating requirements. When the job is finished, all expenses are computed and entered on the record card, Figs. 15 and 15a, one covering each unit of equipment in the plant. The data on these cards are further used in the planning department to analyze what method of repair and what material produces the best results at the lowest cost, and thus leads to continual improvements in this direction.



ELEC. INSPEC. ROUTE CARD

Make the following inspections
in the order named.

Jan. 1 to July 1, 1916.

WATCH 7 - 3 EVEN SUNDAYS

APPARATUS	2	16	30	13	27	12	26	9	23	7	21	4	18		
1. 25 Cy. Gens.	✓	✓													
2. No. 11	✓	✓													
3. No. 13	✓	✓													
4. No. 12	✓	✓													
5. A.	✓	✓													
6. B.	✓	✓													
7. C.	✓	✓													
8. D.	✓	✓													
9. S.	✓	✓													
10. CS	✓	R													
11. T	✓	✓													
12. Coal Larry No.3	✓	✓													
13. Coal Larry No.4	✓	✓													
14. Battery Blower	✓	✓													
15. Economizer	✓	✓													
16. Coal Elevator (Ry)	✓	✓													
17. Coal Crusher	✓	✓													
18. Coal Conveyor	✓	✓													
20. Ventilators	✓	O													
21. Ash Locomotive	✓	✓													
22. Oil Filters	✓	✓													
23. Oil Pump	✓	✓													
24. Control Bench	✓	✓													
25. Feeder Board	✓	✓													
26. Local Ser. Board	✓	✓													
27. Exciter Board	✓	✓													
28. Signal Board	✓	✓													
R-repair suggested O-ordered out.															
SIGNED	I	P													

FIG. 13. Inspection Route Card for Electricians

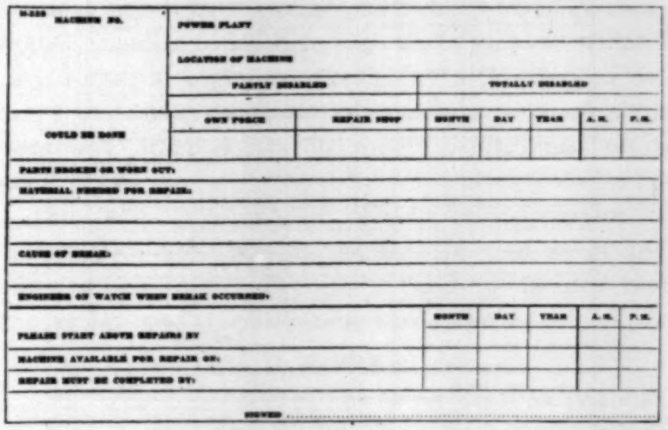


FIG. 14 front

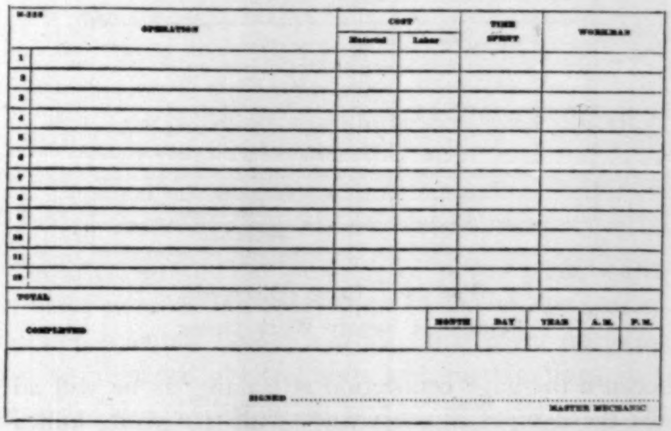
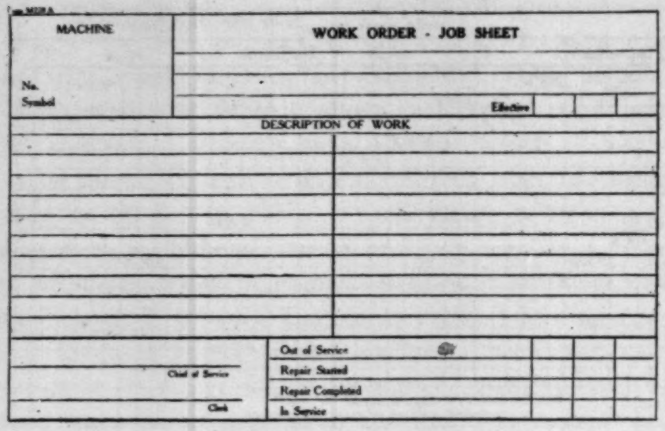


FIG. 14a back

Maintenance of Equipment Inspection Report Card.

As far as stimulation of maintenance men is concerned, they receive their bonus over and above the daily wages only for those days when no interruption in operation occurs on account of their defective maintenance, and they lose their bonus whenever it is proved that the operating men fall short of their tasks on account of poor upkeep. For instance, a fireman fails to secure the expected boiler-efficiency rating,



MACHINE

No.
Symbol

WORK ORDER - JOB SHEET

Effective

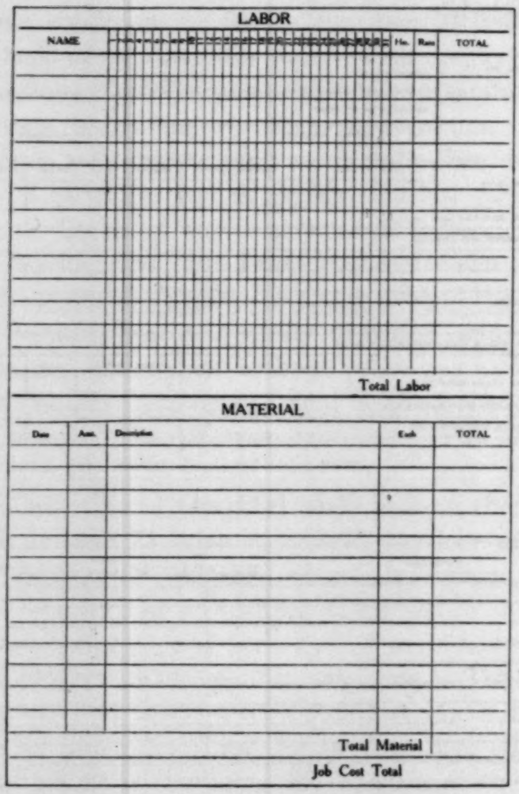
DESCRIPTION OF WORK

Chief of Service

Clerk

Out of Service
Repair Started
Repair Completed
In Service

FIG. 14b front



LABOR

NAME	Hrs.	Rate	TOTAL

Total Labor

MATERIAL

Date	Am.	Description	Each	TOTAL

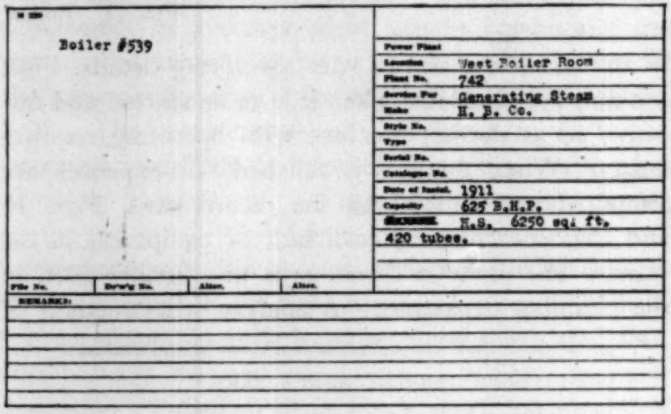
Total Material

Job Cost Total

FIG. 14c. Back (enlarged).
Equipment Repair Work Order.

because the gage connection is leaking, as he will adjust the damper in accordance with the wrong indications. This would be the instrument man's fault, not the fireman's, and while the former will lose his hours, the latter may be allowed his, if nothing else was done wrong. To carry out this plan, it is evidently the duty of the planning department to investigate every failure at once, before the man affected comes back for his next turn; otherwise, the mistake may be unknowingly repeated and a late investigation sometimes will not reveal the real cause.

18. The success of our maintenance method depends in no small degree upon careful selection, standardization and purchase of all supplies and materials. The maintenance-record cards, Figs. 15 and 15a, referred to before are of material assistance for at least abandoning the use of supplies and materials that proved short-lived and expensive. Expensiveness, however, is figured out in the planning department not as cost per pound, foot, or what not, but as cost per time in service of material required for a job, plus labor cost, plus overhead charge during the repair time. Such data often give an effective weapon to fight some short-sighted purchasing agent's hobby to buy the cheapest stuff on the market, or with too general a fancy that the most expensive is the best. Neither of these generalities can, of course, remain true in all cases. In this way, for instance, it was found that a very cheap and comparatively poor qual-



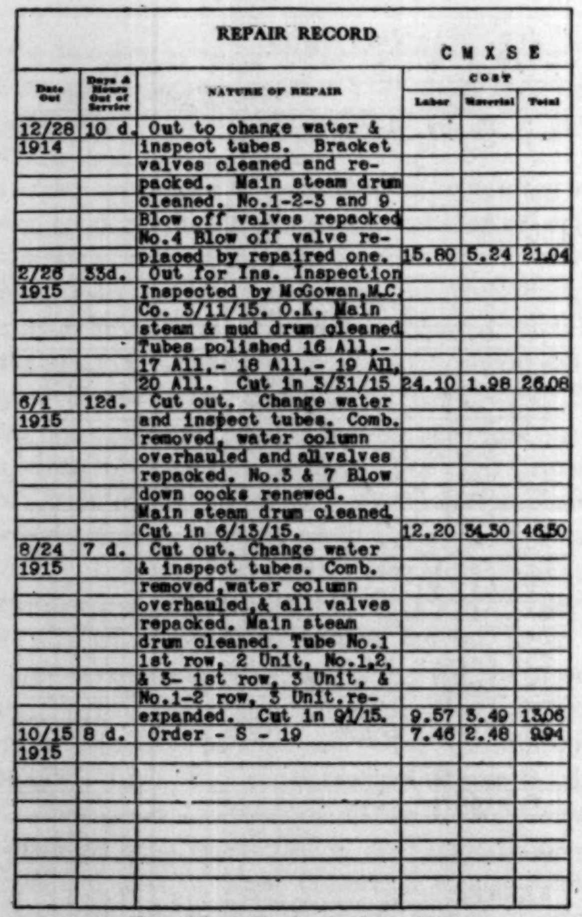
Boiler #539

Power Plant
Location West Boiler Room
Plant No. 742
Service For Generating Steam
Make H. B. Co.
Style No.
Type
Serial No.
Catalogue No.
Date of Install. 1911
Capacity 625 B.H.P.
[illegible] H.S. 6250 sq. ft.
420 tubes.

File No. | Drw'g No. | Alter. | Alter.

REMARKS:

FIG. 15 front



REPAIR RECORD

C M X S E

Date Out	Days & Hours Out of Service	NATURE OF REPAIR	COST Labor	COST Material	COST Total
12/28	10 d.	Out to change water &			
1914		inspect tubes. Bracket			
		valves cleaned and re-			
		packed. Main steam drum			
		cleaned. No.1-2-3 and 9			
		Blow off valves repacked			
		No.4 Blow off valve re-			
		placed by repaired one.	15.80	5.24	21.04
2/26	33d.	Out for Ins. Inspection			
1915		Inspected by McGowan, M.C.			
		Co. 3/11/15. O.K. Main			
		steam & mud drum cleaned			
		Tubes polished 16 All,-			
		17 All,- 18 All,- 19 All,			
		20 All. Cut in 3/31/15	24.10	1.98	26.08
6/1	12d.	Cut out. Change water			
1915		and inspect tubes. Comb.			
		removed, water column			
		overhauled and all valves			
		repacked. No.3 & 7 Blow			
		down cocks renewed.			
		Main steam drum cleaned.			
		Cut in 6/13/15.	12.20	34.30	46.50
8/24	7 d.	Cut out. Change water			
1915		& inspect tubes. Comb.			
		removed, water column			
		overhauled, & all valves			
		repacked. Main steam			
		drum cleaned. Tube No.1			
		1st row, 2 Unit, No.1,2,			
		& 3- 1st row, 3 Unit, &			
		No.1-2 row, 3 Unit, re-			
		expanded. Cut in 9/1/15.	9.57	3.49	13.06
10/15	8 d.	Order - S - 19	7.46	2.48	9.94
1915					

FIG. 15a. Back (enlarged).
Maintenance Work Card for Equipment Repairs.

ity firebrick gave excellent results if used in conjunction with somewhat expensive fireclay cement, or that expensive grease for cylinder lubrication was cheaper to use than the cheapest cylinder oil, etc.

The most important material used in the power-plant is, of course, fuel. It has little influence on maintenance, but is a deciding factor on the cost of operation. The old Chinese custom to pay a ransom for the bride in proportion to her weight is still prevailing among coal buyers and dealers. The attempts made to buy fuel on the basis of its heat value, steaming capacity, etc., with penalties and premiums for certain composition by approximate analysis, proved beyond any doubt that the knowledge of the composition of coal and maintaining the quality of supply uniform are of paramount importance for securing uniform results as good as other conditions permit. It is therefore quite necessary that the planning department keep a watch on this subject and, with every change in the composition of coal, authorize the necessary research in the best use of this grade if it is not standardized already. The heating value of the coal, however, has no influence on the method as a rule, except in cases of wide fluctuations; but its effect on the result is automatically adjusted in figuring out the boiler and furnace efficiency. A convenient method of keeping tab on the quality, quantity and time of coal deliveries is exhibited in the chart Fig. 16.

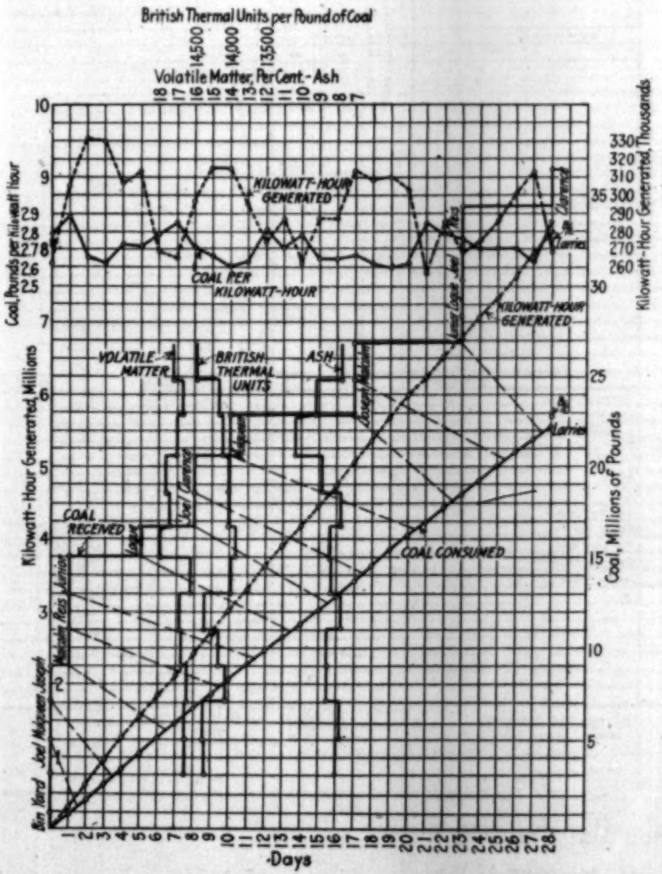


Fig. 16. Coal Movement Record.

19. To enable an efficient and uninterrupted conduct of any operation, the storeroom service shall be well regulated, but in a power plant this function takes on a special aspect.

The largest bulk of material that is used is coal. If spacious coal storage is not provided or handling is expensive, the quantity of coal on hand must be kept as low as permissible, considering the transportation and deliveries. Small supply of coal on hand is also sometimes desirable from the viewpoint of reducing interest charges. Besides, certain grades of coal deteriorate rapidly and some are subject to spontaneous combustion. Again, all deliveries being not equal in quality and characteristic therefore the mixing of various coals is undesirable. All these facts complicate the problem of planning the coal supply and storage, and the previously mentioned Schaller's diagram, Fig. 16, is very serviceable as it shows at a glance quantity, quality, rates of delivery and use, dates of shipments, means of shipment and other useful information combined on a small chart.

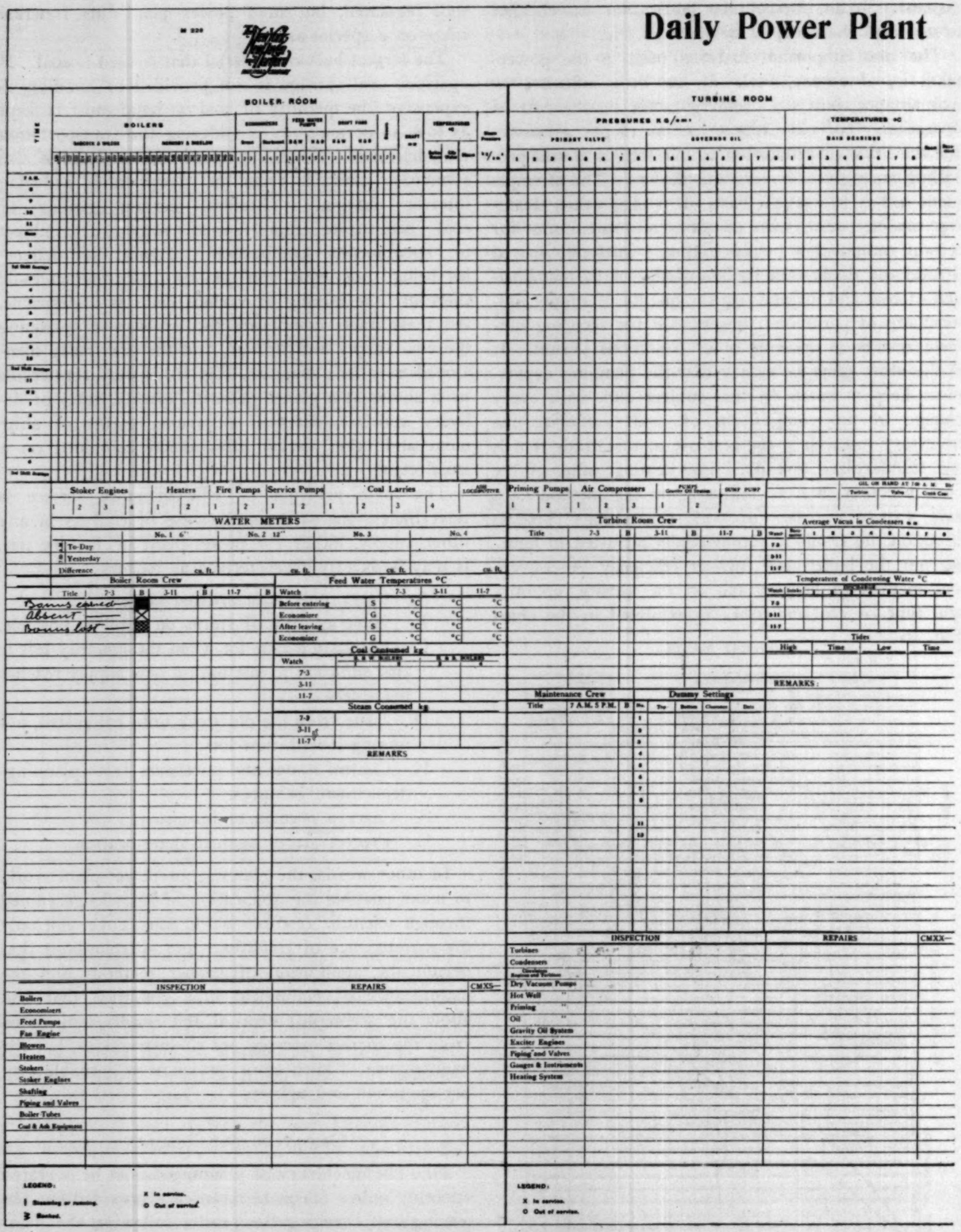
The main principle of efficient store service is nevertheless the same in the case of coal as in any other supply, either for power-plant or factory use. It may be briefly characterized as follows:

A. Carry only standardized stores.
B. Have as little of stores on hand as possible.
C. Purchase a new lot when the quantity left is just sufficient to last until a new supply reaches the stores.
D. Issue from the old stock until exhausted, not mixing it with new lots.
E. Control issues and purchases from planning-department balances.
F. Carry a permanent inventory.
G. Protect stores against deterioration.

In other words, the planning of power-plant work, to make possible the application of knowledge gained through scientific research work, must cover not only the maintenance of conditions and surroundings that permit the application of proper methods and the maintenance of equipment in a condition that will allow the accomplishment of the results anticipated from the correct carrying out of instructions, but the maintenance of such store service as will enable proper operation and upkeep.

Observing the Results

20. The machinery of planning cannot be operated smoothly unless adequate means are provided for observing and checking the results following the planning done in the past. There is no need here to go into a detailed discussion as to what recording or indicating instruments are indispensable for economic



M 220

Daily Power Plant

BOILER ROOM

BOILERS

TIME

7 A.M.

TURBINE ROOM

PRESSURES KG/cm²

PRIMARY VALVE

GOVERNOR OIL

TEMPERATURES °C

MAIN BEARINGS

Stoker Engines				Heaters		Fire Pumps		Service Pumps		Coal Larries				Ash Locomotive
1	2	3	4	1	2	1	2	1	2	1	2	3	4	

WATER METERS

	No. 1 6"	No. 2 12"	No. 3	No. 4
To-Day				
Yesterday				
Difference	cu. ft.	cu. ft.	cu. ft.	cu. ft.

Boiler Room Crew

Title	7-3	B	3-11	B	11-7	B
Bonus earned —		■				
Absent —		☒				
Bonus lost —		▩				

Feed Water Temperatures °C

Watch		7-3	3-11	11-7
Before entering	S	°C	°C	°C
Economizer	G	°C	°C	°C
After leaving	S	°C	°C	°C
Economizer	G	°C	°C	°C

Coal Consumed kg

Watch	B. & W. Boilers 1	2	H. & B. Boilers 3	4
7-3				
3-11				
11-7				

Steam Consumed kg

7-3				
3-11				
11-7				

REMARKS

Priming Pumps		Air Compressers			Pumps Gravity Oil System		Sump Pump
1	2	1	2	3	1	2	

Oil on hand at 7:00 A. M.

Turbine	Valve	Crank Case

Turbine Room Crew

Title	7-3	B	3-11	B	11-7	B

Average Vacua in Condensers mm

Watch	Barometer	1	2	3	4	5	6	7	8
7-3									
3-11									
11-7									

Temperature of Condensing Water °C

Watch	Intake	1	2	3	4	5	6	7	8
7-3									
3-11									
11-7									

Tides

High	Time	Low	Time

REMARKS:

Maintenance Crew

Title	7 A.M. 5 P.M.	B

Dummy Settings

No.	Top	Bottom	Clearance	Date
1				
2				
3				
4				
5				
6				
7				
8				
11				
12				

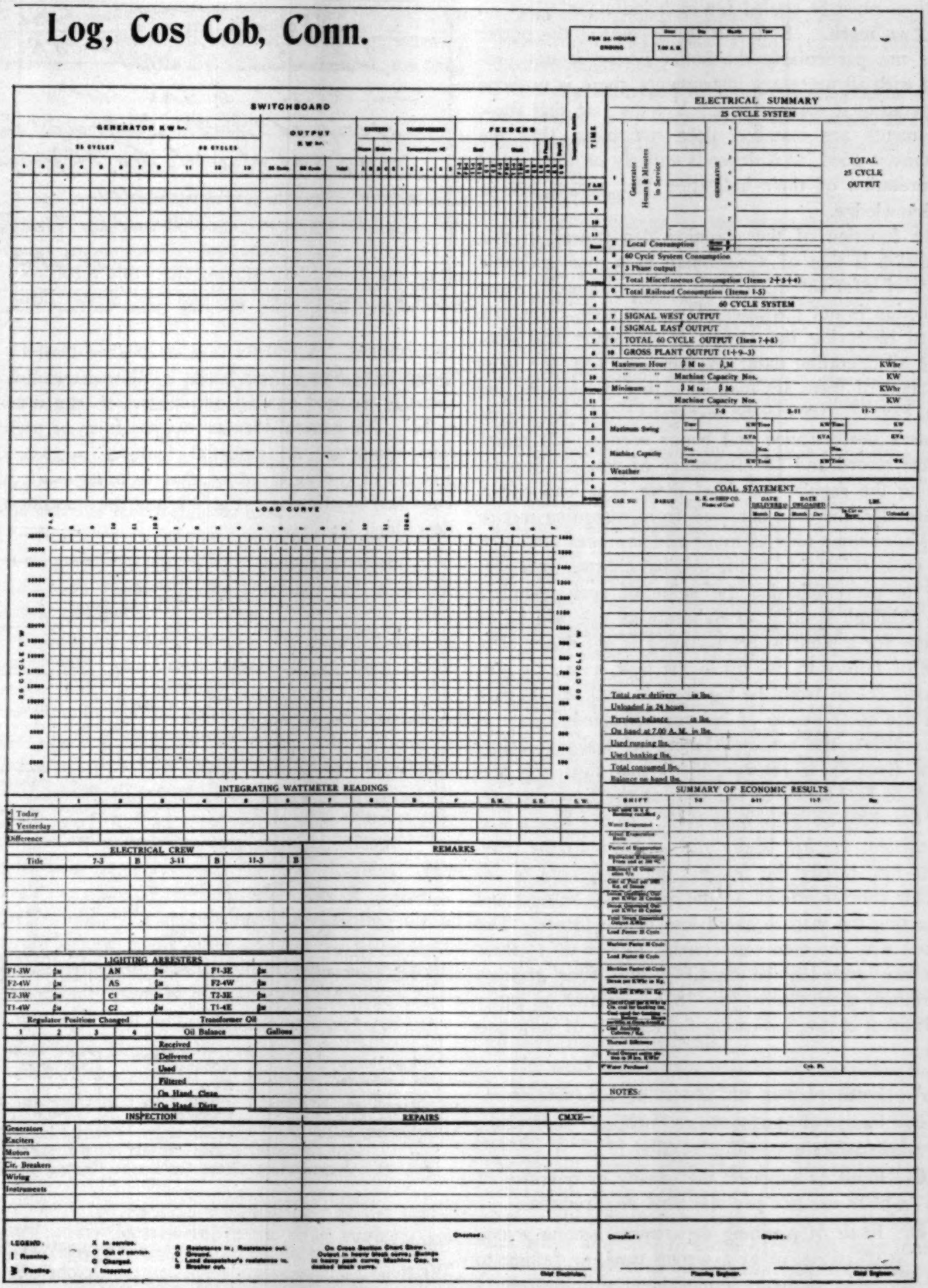
	INSPECTION	REPAIRS	CMXS—
Boilers			
Economizers			
Feed Pumps			
Fan Engine			
Blowers			
Heaters			
Stokers			
Stoker Engines			
Shafting			
Piping and Valves			
Boiler Tubes			
Coal & Ash Equipment			

	INSPECTION	REPAIRS	CMXX—
Turbines			
Condensers			
Circulating Engines and Turbines			
Dry Vacuum Pumps			
Hot Well "			
Priming "			
Oil "			
Gravity Oil System			
Exciter Engines			
Piping and Valves			
Gauges & Instruments			
Heating System			

LEGEND:
| Steaming or running.
Ƶ Banked.
X In service.
O Out of service.

LEGEND:
X In service.
O Out of service.

FIG. 17. CENTRAL STATION LOG FORM.
(Left half only. For right half see page 17.)



Log, Cos Cob, Conn.

FOR 24 HOURS ENDING 7.00 A.M.

SWITCHBOARD

GENERATOR KW hr. — 25 CYCLES — 60 CYCLES

OUTPUT KW hr.

FEEDERS

TIME

7 A.M., 8, 9, 10, 11, Noon, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6

ELECTRICAL SUMMARY

25 CYCLE SYSTEM

1 Generator Hours & Minutes in Service — GENERATOR 1, 2, 3, 4, 5, 6, 7, 8 — TOTAL 25 CYCLE OUTPUT

2	Local Consumption	
3	60 Cycle System Consumption	
4	3 Phase output	
5	Total Miscellaneous Consumption (Items 2+3+4)	
6	Total Railroad Consumption (Items 1-5)	

60 CYCLE SYSTEM

7	SIGNAL WEST OUTPUT	
8	SIGNAL EAST OUTPUT	
9	TOTAL 60 CYCLE OUTPUT (Item 7+8)	
10	GROSS PLANT OUTPUT (1+9-3)	

Maximum Hour .... M to .... M .... KWhr

" " Machine Capacity Nos. .... KW

Minimum " .... M to .... M .... KWhr

" " Machine Capacity Nos. .... KW

	7-3	3-11	11-7
Maximum Swing	Time ... KW KVA	Time ... KW KVA	Time ... KW KVA
Machine Capacity	Nos. Total ... KW	Nos. Total ... KW	Nos. Total ... KW

Weather

COAL STATEMENT

CAR NO.	BARGE	R. R. or SHIP CO. Name of Coal	DATE DELIVERED Month	DATE DELIVERED Day	DATE UNLOADED Month	DATE UNLOADED Day	LBS. In Car or Barge	LBS. Unloaded

Total new delivery in lbs.

Unloaded in 24 hours

Previous balance in lbs.

On hand at 7.00 A. M. in lbs.

Used running lbs.

Used banking lbs.

Total consumed lbs.

Balance on hand lbs.

SUMMARY OF ECONOMIC RESULTS

SHIFT	7-3	3-11	11-7	Day
Coal used in K.g. Banking excluded				
Water Evaporated				
Actual Evaporation Ratio				
Factor of Evaporation				
Equivalent Evaporation From and at 100° C.				
Efficiency of Generation %				
Cost of Fuel per 1000 Kg. of Steam				
Steam Generated Out per KWhr 25 Cycles				
Steam Generated Out per KWhr 60 Cycles				
Total Steam Generated Output KWhr				
Load Factor 25 Cycle				
Machine Factor 25 Cycle				
Load Factor 60 Cycle				
Machine Factor 60 Cycle				
Steam per KWhr in Kg.				
Coal per KWhr in Kg.				
Cost of Coal per KWhr in Cts. coal for banking inc.				
Coal used for banking — Boilers Hours per KWhr as Gross Output				
Coal Analysis Calories / Kg.				
Thermal Efficiency				
Total Output ... in 24 hrs. KWhr				
Water Purchased			Cu. Ft.	

NOTES:

LOAD CURVE

25 CYCLE K W — 60 CYCLE K W

INTEGRATING WATTMETER READINGS

	1	2	3	4	5	6	7	8	9	F	S.W.	S.E.	S.W.
Today													
Yesterday													
Difference													

ELECTRICAL CREW

Title	7-3	B	3-11	B	11-3	B

REMARKS

LIGHTING ARRESTERS

F1-3W	...M	AN	...M	F1-3E	...M
F2-4W	...M	AS	...M	F2-4W	...M
T2-3W	...M	C1	...M	T2-3E	...M
T1-4W	...M	C2	...M	T1-4E	...M

Regulator Positions Changed

1	2	3	4

Transformer Oil

Oil Balance	Gallons
Received	
Delivered	
Used	
Filtered	
On Hand, Clean	
On Hand, Dirty	

INSPECTION		REPAIRS	CMXE—
Generators			
Exciters			
Motors			
Cir. Breakers			
Wiring			
Instruments			

LEGEND:

| Running.

Floating.

X In service.

O Out of service.

C Charged.

I Inspected.

R Resistance in; Resistance out.

G Ground.

L Load despatcher's resistance in.

B Breaker out.

On Cross Section Chart Show: Output in heavy black curve; Swings in heavy peak curve; Machine Cap. in dashed black curve.

Checked: .... Chief Electrician.

Checked: .... Planning Engineer.

Signed: .... Chief Engineer.

FIG. 17. CENTRAL STATION LOG FORM.
(Right half only. For left half see page 16.)

operation or what data shall be recorded. All these questions must be settled for each individual plant on their own merit. Suffice it to say that if the power plant, and particularly the boiler house, is not provided with all necessary instruments, there is no hope of operating it economically. Yet the fact that these instruments are installed does not mean that the economy is good, as it depends entirely on the correct interpretation of their indication and proper use of this knowledge.

The function of the planning department in this connection is that of a custodian of a most valuable source of information, without which economic power production is not possible. The first step, therefore, toward observing the results is collecting and analyzing all operating data. A fair idea what the most important of them are may be gathered from the log form, Fig. 17. Its specific features are (1) the record of men's performance and bonus earned, (2) maintenance record and (3 summary of result. Supplementing the regular log-data, there is a load curve. Incidentally, the data obtained from recording instruments are shown only as totals and averages per shift, with cross-references to the original charts. It is difficult to overemphasize the value of such complete logs, although nothing so elaborate as this will be of any use for a plant where planning is not done. The cause of failure to live up to the task, as a rule, can be easily traced from the log records, and only in rare cases are other means of information needed.

21. When the accomplishment of tasks is determined from these returns, the bonus slips are prepared, to be handed to the men at the time they report for duty on their next shift. If the bonus was not earned, the lost-bonus slip is given to the man, telling him briefly the reason; the work boss or instructor further attends to the matter by helping and instructing the man to avoid loss in the future. The reasons why the men were unable to live up to their tasks can generally be classified into four groups; accordingly these forms, Fig. 18, are printed on paper of different colors, indicating the location of responsibility:

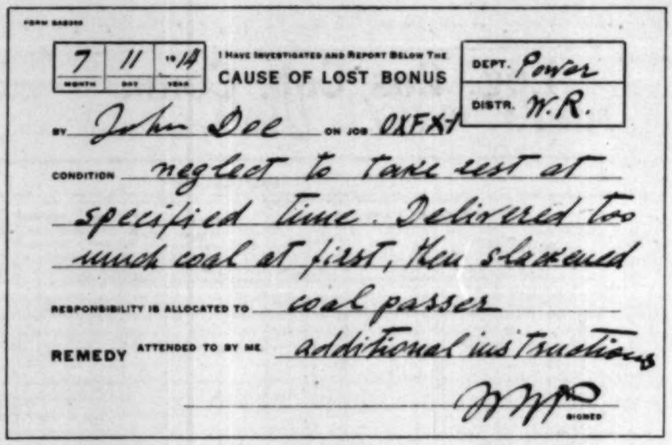
A. Fault of man not observing instructions.

B. Fault of maintenance making observance impossible or spoiling results.

C. Fault of supplies, the quality or quantity of which was not per standard requirements.

D. Fault of planning department issuing wrong instructions, or at a wrong time, or failing to provide necessary implements, training, etc.

Lost-bonus slip issue is an authority and order for immediate investigation, and upon the receipt of the report, steps are at once taken to prevent similar occurrences. Whenever it is established that the man is not to be blamed, his bonus is allowed and this payment is charged against administration expenses.



7 / 11 / 1914 (MONTH / DAY / YEAR)	I HAVE INVESTIGATED AND REPORT BELOW THE CAUSE OF LOST BONUS	DEPT. Power DISTR. W.R.

BY John Doe ON JOB OXFX1

CONDITION neglect to take rest at specified time. Delivered too much coal at first, then slackened

RESPONSIBILITY IS ALLOCATED TO coal passer

REMEDY ATTENDED TO BY ME additional instructions

SIGNED

Fig. 18. Report Slip Showing Cause of Lost Bonus.

22. The general idea as to what form of organization comprises all essential features necessary for successful carrying out of the planning work is exemplified by the chart, Fig. 19, and the standing order describing it:

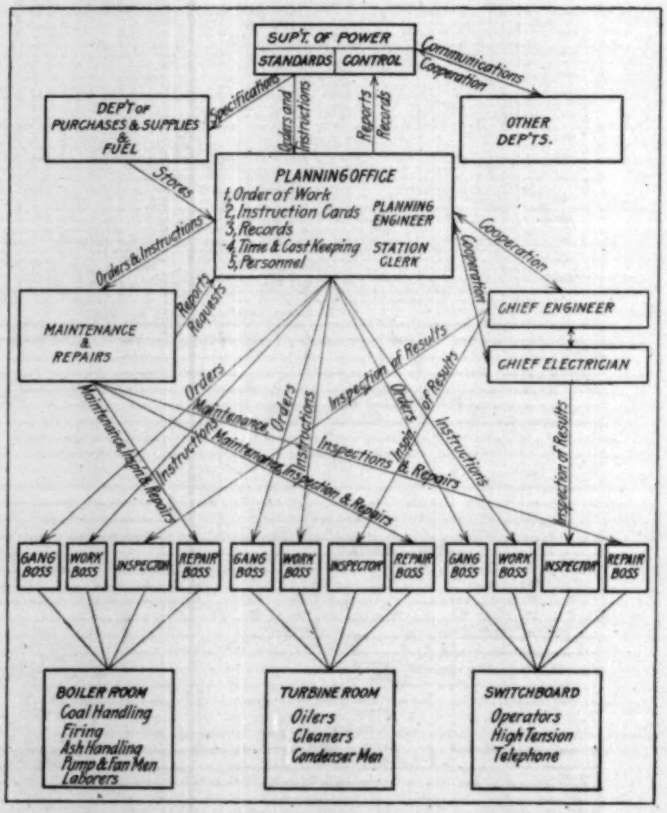


Fig. 19. Organization Chart for Large Central Station.

Standing Order No. 5

Subject .... Organization Chart
Written .... October 8, 1914
To go into effect .... October 15, 1914
Superseding . All previous verbal and written orders
Affecting .... Cos Cob Organization

A. **Object of Order.**

This order is issued to clearly define the organization chart of the Cos Cob Power Plant of the New York, New Haven & Hartford Railroad Co., showing the division of duties of various officials and their subordinates.

B. Description of Organization Chart.

See Exhibit "A."

This chart is based on functional management instead of line foremanship. It shows to whom each department and member of the organization is responsible for different functions.

The arrows show the direction in which the order of work, instruction, requests and reports are transmitted.

C. Definition of Sections:

The organization of plant is engaged upon two different kinds of work—planning and execution.

D. Planning Section:

The planning office is under the supervision of the superintendent, and the planning engineer in charge of the office is responsible to him.

The functions of the planning office are as follows: (a) Order of work; (b) Instruction cards; (c) records; (d) time and cost keeping; (e) personnel, including discipline.

The planning office receives all requests and coöperates with: (a) Chief engineer; (b) chief electrician; (c) chief maintenance man.

The planning office reports to the superintendent of power on the progress of work and success of methods and transmits to the office of the superintendent of power all records kept in the plant.

The organization of coöperation with other departments, ordering and receiving supplies, material, and outside help is performed by the planning office through the office of the superintendent of power.

The planning engineer is made responsible for all work performed in his office and for the living up to the standards and instructions worked out by the chief engineer, chief electrician or chief maintenance man, and approved by the superintendent of power.

E. Executive Section:

The chief executive of the plant is the chief engineer, and all employees of the plant are responsible to him for the proper discharge of their duties, discipline and living up to the planning-office orders.

F. Chief Electrician:

The chief electrician is responsible, for the results obtained in his department, to the chief engineer and reports to him.

G. Chief Maintenance Man:

The chief maintenance man is responsible to the chief engineer as to result of the work in his department and reports and receives orders through the planning office.

H. Functional Foremen:

The entire plant is divided into three groups: (a) boiler room; (b) turbine room; (c) switchboard and electric department.

The work in each of these departments is directed and inspected by four functional foremen, as follows: (a) gang boss; (b) work boss; (c) inspector; (d) repair boss.

I. Gang Boss:

He takes charge of the preparation of conditions necessary for performing the work in his department.

In the boiler room he sees that coal is delivered to the stokers in time and in the necessary quantity to each boiler; that water is fed to the boilers in the proper manner by the proper pump; that each man has definite boilers assigned to him, and that all necessary firing tools, instruction cards, instruments, etc., are given to the men.

In the turbine room he sees that the valves are set right; that the piping is properly connected; that auxiliaries are in readiness for operation; that all assistants and oilers are assigned to their respective jobs; that each unit, except those taken out for repair, is ready for service at a moment's notice, and that men attending the equipment are supplied with proper instructions, tools, instruments, etc.

On the switchboard the gang boss sees that all high-tension equipment is properly connected; that switches and instruments are in readiness for use; that those affected in any way are properly tagged and instructions and orders from the chief electrician, planning department and load dispatcher are transmitted to the men in an unmistakable way; that each man on the switchboard and in the high-tension room has definite duties assigned to him, and that all necessary instructions and implements are given to the men.

J. Work Boss:

He is responsible as to how the work is performed by his men, and it is his duty to instruct the men how to work in accordance with the standards prescribed on their instruction cards.

The work boss of the boiler room sees that the coal is fed into the furnace at the proper rate; that stoker engines and mechanisms are running at the right speed; that the depth of fuel is in accordance with instruction cards; also that the draft is always in accordance with instructions for the given rate of drive. He instructs the firemen when to shake grates, and when and how to clean fires. He must not only advise his men how best to do their work, but must actually demonstrate the best way of doing it, and he constantly trains the firemen.

The work boss in the turbine room sees that all valves and governors are operated in the right manner; that turbines, engines and auxiliaries are running at the proper speed and are properly oiled; that condensers maintain specified vacuum, and that all other productive and auxiliary machinery, either steam or electric, is taken care of in accordance with respective instruction cards. He instructs all men on the turbine floor, basement, etc., how to live up to instruction cards and attain the best possible result, if necessary actually demonstrating the best way of doing the work, and he constantly trains all men in his gang.

The work boss on the switchboard attends to all switching and instructs all electrical men on duty on the switchboard gallery or in the high-tension room how to perform their duties in accordance with the respective instruction cards. He sees that readings of the proper instruments are taken at the specified time; that telephone and telegraph communications are properly transmitted; that transformers, oil switches and other electric apparatus are receiving the proper care, and if necessary, actually demonstrates to the men of his gang the best way of doing the work, as described in the instruction card, and constantly trains all the men in performing their duties.

K. Inspector.

The inspector's duties in each section of the power house are performed by the chief engineer. Assistant chief engineers are assigned by him to do inspection and supervision of the work done in the boiler room and the turbine room by the gang and repair boss, as well as by the men working under their orders. Assistant chief engineers also look into and report to the chief engineer, whether the coöperation between the boiler room and turbine room with the electrical branch is carried out to the best advantage.

The duties of the inspector of the electrical department of the plant are performed by the chief electrician, who reports his findings to the chief engineer. Assistants to the chief electrician are assigned by him to inspect the work performed on the switchboard, high-tension room and the electric machinery of whatever description elsewhere in the plant. They also inspect the maintenance and repair work on said machinery.

L. Repair Boss:

The chief maintenance man is responsible for all running repairs, as well as betterment work and new installations that are made by his department in accordance with the order delivered to him from the chief engineer or chief electrician through the planning office, and performed in accordance with work order and instruction cards furnished to him by this office. He supervises and performs all the repair and maintenance work in and about the power plant, either personally or through the men assigned to this work.

He is responsible for any unsatisfactory work done on any unit of equipment on the plant premises, and to that end he constantly inspects, examines and tests all units of equipment and reports to the planning department, either direct or through the chief engineer, his recommendations as to cleaning, repairing, overhauling, etc., of any unit of equipment on the plant premises, suggesting the respective importances of the recommended jobs and the sequence in which they shall be done.

M. General:

It will be seen that the organization chart defines the scope of the planning and executive section; that the chief executive, that is, the chief engineer, is in constant touch with the planning office, directing its work and approving all standards and methods, and inspects all results obtained in the plant in the process of the work, as well as the financial result. The planning office relieves the executive from the planning of work and standardization of methods and instructs the respective foremen as to when and how to do the work.

After the work is performed and the inspector's report obtained at the planning office, the planning office collects its own records and works them up in the prescribed manner into reports of both technical and financial nature.

More detailed description of scope of authority, subordination and duties of each official mentioned in the organization chart will be covered by subsequent standing orders.

Approved:

G. W. WILDIN,
Mech. Supt.

WALTER N. POLAKOV,
Supt. of Power.

23. Inasmuch as the cost of power is the final criterion of the success of work, the cost-keeping deserves special attention. Proper distribution and classification of plant expenses should receive, therefore, due consideration. There are three main groups of plant expenses:

A. Direct expenses—directly chargeable to the operation and upkeep.
B. Indirect expenses—all expenses general in character and indirectly concerned with operation and upkeep.
C. Auxiliary expenses—for such departments and services that may be rendered by independent concerns.

Direct expenses consist of fuel, labor, supplies, etc., that are directly converted into power generated in the plant. They also embrace such upkeep work as is being done in regular routine by the operating force, but do not include machine-shop expenses and the like.

Indirect expenses may be further subdivided:

A. Management, general administration, planning etc., except departmental supervision.
B. Storeroom purchasing-agent expenses.
C. Rental expenses, including interest, taxes, insurance, depreciation, heat, light and power, etc.
D. Maintenance.
E. Departmental supervision.

All these expenses must be distributed over the entire plant, and the proportion that falls on the idle part of the plant must be shown separately. This proportion is taken from the log record of idle equipment, and is called "Unapplied Indirect Expenses;" the other indirect expenses are pro-rated over the net output.

Auxiliary expenses cover machine shop, pumping station, stable or plant locomotives and all such expenses for services that could be bought from outside and independent establishments.

24. Such a grouping as this makes it possible to judge the value of services received for the expense incurred. Direct or operating expenses can be comparatively easily predetermined with great precision, as the author described in several previous papers. Standard or alloted expense per unit of output for any rate of load and under variable conditions thus becomes a gage for measuring the efficiency of operating methods. A diagram of such predetermined operating expenses is shown in Fig. 20. Indirect expenses, once disbursed between active and idle portions of the plant or departments, render the criterion for rationality of overequipping the plant in anticipation of breakdowns or growth of future demand.

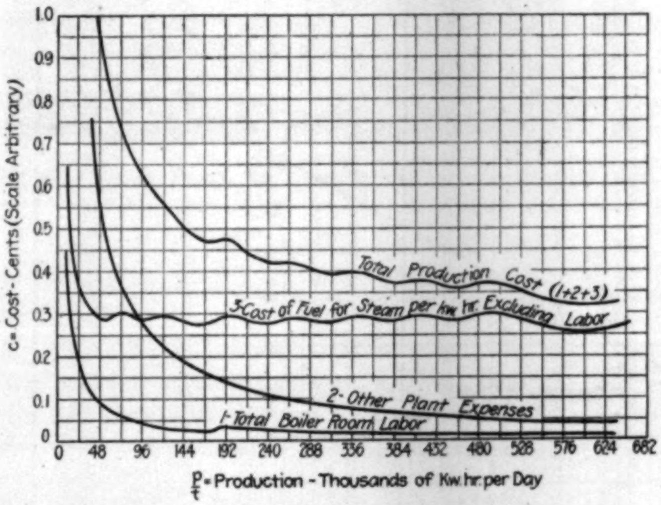


FIG. 20. Diagram Showing Predetermined Operating Cost.

Auxiliary expense accounts, kept in accordance with this classification, help to determine whether it is profitable to own these facilities or better to secure them from independent sources. The amount and proportion of the idle expenses on these auxiliaries will show to what extent they are made use of. The necessary and sufficient expenses, both of the indirect and auxiliary groups can also be predetermined, although not with the same positive precision as the operating expenses. In other words, the properly carried analysis makes it possible to satisfy the long-felt need of having the gage by which the efficiency of the plant management can be measured.

25. It thus becomes possible for the planning office to watch the results accomplished in the plant under its direction. Whereas the exact knowledge to a penny of all expenses incurred is satisfied by accounting and bookkeeping, for those directing the work the snap information as to the trend of progress is more valuable. To satisfy this need, the planning department keeps a number of easily understood records in graphic form. For this purpose all the important records are kept in the form of charts similar to Fig. 21. The summaries of output, plant's thermal efficiency and machine factor are kept on the board by means of colored strings stretched between nails, Fig. 22. Enough has been said and written concerning the value to operating crews and busy executives of such immediate, accurate and easily understood graphic records, so that we merely mention it here in passing, to emphasize the advantages of having these data posted for the information of all employees without making of them a business secret. We have never found anything more efficacious to stimulate the feeling among the employees

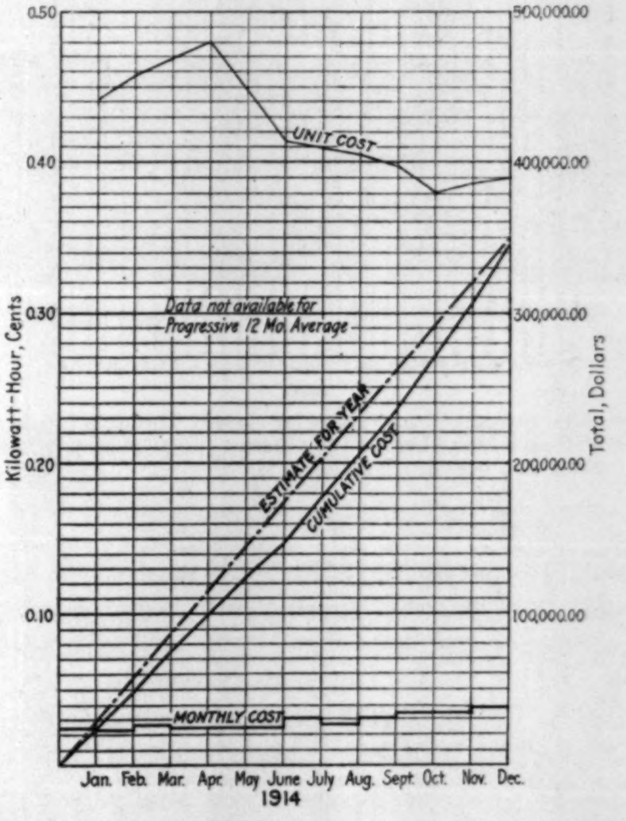


FIG. 21. Graphic Expense Record showing Cost of Fuel.

of all departments that they, like the musicians in a band, while doing their individual shares of work in the right manner, can justly pride themselves in the concerted accomplishment.

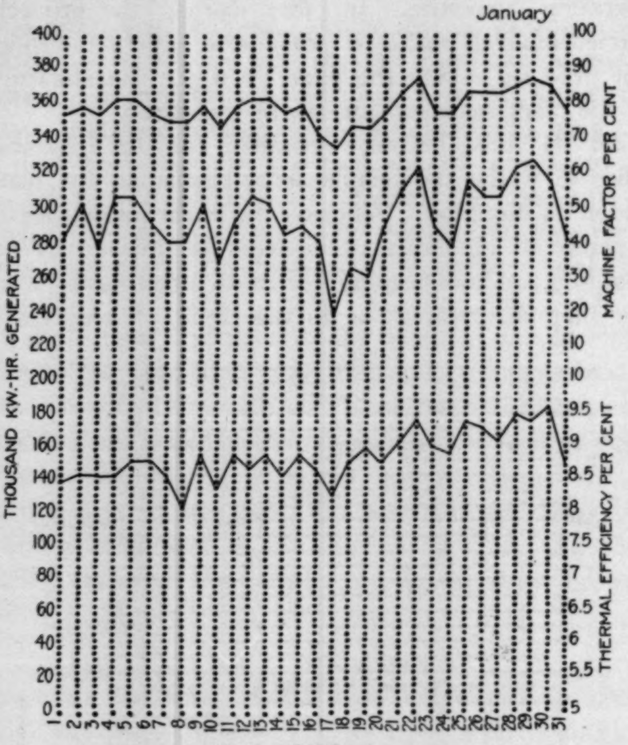


FIG. 22. Bulletin Board Showing Load, Thermal Efficiency and Machine Factor by means of Colored Strings Stretched between Nails.

SUMMARY

26. To sum up, the planning of power-plant work is the most important function of the management. It comprises and harmonizes every activity, controls and directs every function, every process, every method. While the process of generating power is a complicated thermodynamic process, conditioned by laws of chemistry, physics, etc., no management can succeed unless it is thoroughly familiar with all underlying principles. Yet no matter how thorough is the knowledge of the physical side of the game, *the success of securing the best results depends not on the perfection of equipment and supplies, but on the value of methods used.*

In a power plant whether small or large, the following managerial functions must be performed:

A. Planning to meet the requirements of operation and maintenance, including schedules, standards, etc.

B. Superintending, including task determination, bonus, inspections, discipline, etc.

C. Recording, including time and cost keeping, balance of stores, engineering records and logs.

In order to successfully carry the routine work of the planning office, it must be provided with all necessary standards as to methods, materials and equipment. For the majority of plants this work may best be done by an outside organization, or staff of specialists. Once the work is started right, the perpetuation of researches, revision of standards and the like, must be carried out by a special engineering bureau embracing an information service.

In a large plant the cost of the planning department, although large, cannot be noticed on a payroll, as it simply means that *all the planning work formerly done in the boiler room, coal pockets, switchboard gallery and repair shop is now cèntralized in one place, and properly coördinated.* The diagram, Fig. 23, shows the payroll for a large electric-railroad central station. Although during the first

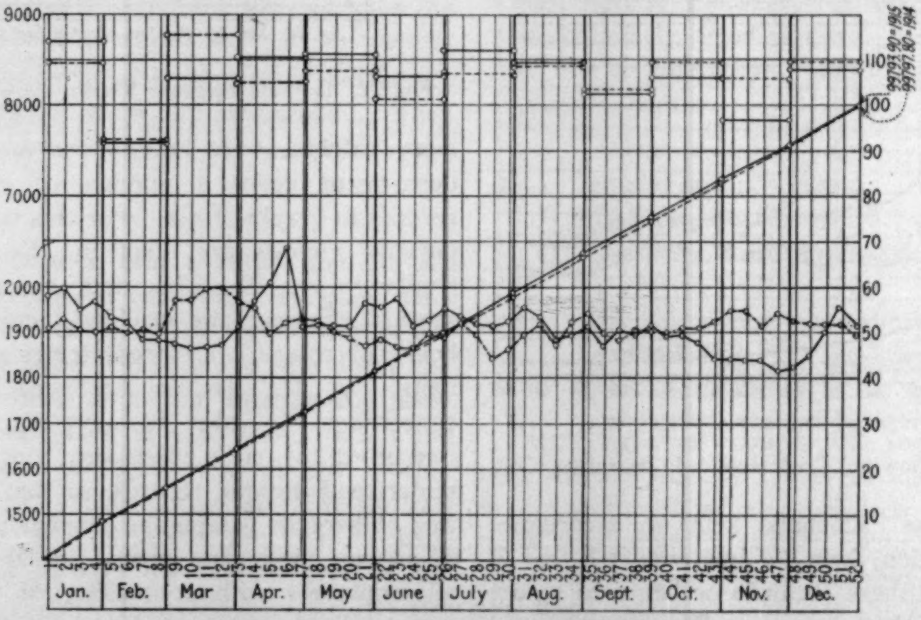


FIG. 23. Diagram showing Total Pay-roll before and after Planning Department was added to the organization.

year on record here was no planning department and during the second year such a department was organized, equipped and manned, the total payroll remained practically the same for both.

In a small power plant for a factory, it is possible to carry on practically all the planning work by a clerk directed by a high-class experienced engineer, or even from an outside consulting office, thus requiring only a very moderate appropriation compared with the large savings accomplished through such an organization. Figs. 24 and 25 show a 34000-kw. plant and its planning office, Fig. 26 a work-order route board, and Fig. 27 the ticket side of a planning board.

In conclusion the writer wishes to emphasize the fact, often obscured by details pertaining to scientific management, that it is not forms, nor time studies, neither store system, nor classifications, however excellent, that are important in bringing about the desired result, but the scientific and humanitarian attitude in which all these detail problems are solved.

FIG. 24. A 34,000 K. W. Power Plant.

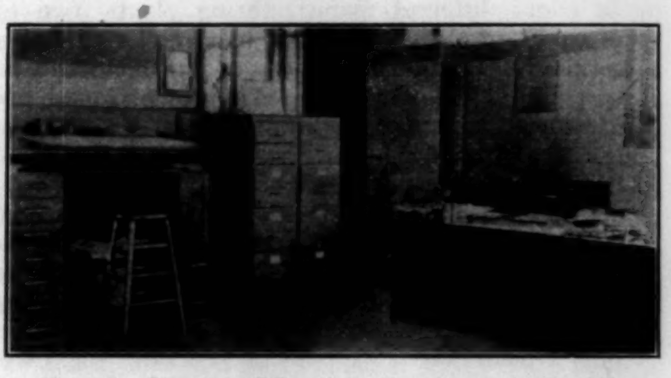


FIG. 25. Planning Office for plant shown in Fig. 24.

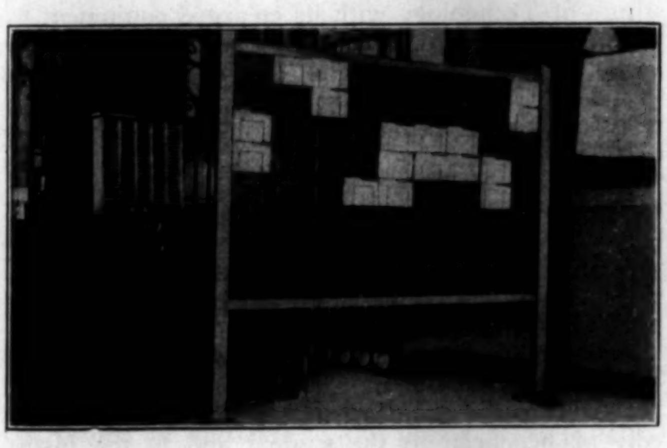


FIG. 26. Route Board in Planning Room, work order side.

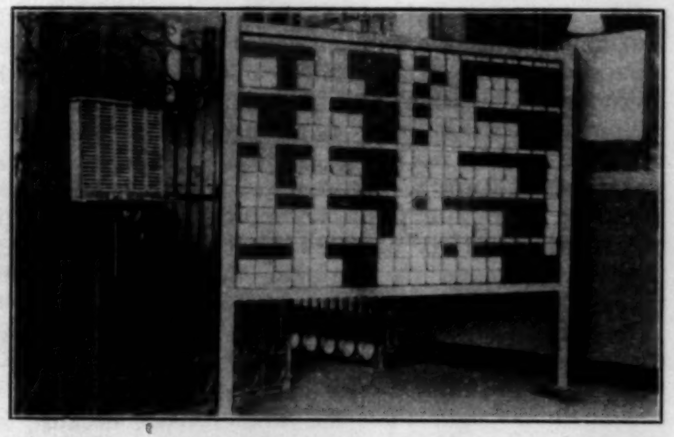


FIG. 27. Route Board in Planning Room, time ticket side.

DISCUSSION

Mr. H. P. Kendall:[1] I should like to say, in the first place, how pleased I am to have a paper of this character delivered here, a paper on a subject that all of us are bound to be more or less interested in. Every industrial plant has a power plant, and it is the part of the works which the management generally knows the least about, and it is one of the departments which is likely to give the most annoyance. I looked forward to hearing Mr. Polakov with a good deal of interest, because I had heard about him, and had heard about his work, and his work strikes at one of the points that is troublesome to me.

My situation is an interest in four steam plants, in as many different manufacturing plants, two of them equipped each with three main boilers running a working steam pressure of about one hundred and forty pounds, and two equipped with horizontal fire tube boilers, running a working steam pressure of ninety to one hundred and twenty-five pounds. Two of them according to old standards are fairly efficiently managed. Two of them according to the same standards are very inefficiently managed. The average works manager or superintendent of plant knows very little about the steam end, and he relies, if he has a good engineer, absolutely on the engineer. If it is a plant which supplies or generates its power by water, and runs the steam plant only for steam, the steam plant is likely to be, as in the case of one that I am interested in, in the hands of a rather inefficient head-fireman.

The thing that I should like to ask Mr. Polakov is: just how far are his methods applicable and profitable to a small steam plant such as I have described? I quite agree with him that the management needs to be tackled first in most every problem of scientific management. I am going to admit that right at the start and welcome it, but most of his discussion this morning was quite properly applied to large steam plants, public utility plants. What interests me, and probably interests most of the men here, is small plants that we are running ourselves.

Mr. Polakov: The answer to the question how these principles could be applied to the small industrial plant is simple. You cannot make one link of the chain stronger than the whole chain, because it is of no use. If the industry is inefficient, if the manufacturing department is badly managed, there is no use making the power plant exceptional. If everything but the power plant is well managed, the only thing to do is to let the planning department of the manufacturing concern extend its function to the power plant. It consumes only a fraction of the time of different clerks handling certain features and of engineers handling other features to bring the power plant up to par. If their own engineers are not competent to inaugurate the system, the help of outside engineers will be necessary to start things. For handling small isolated plants, not equipped to solve effectively their own power plant problems, Germany, Russia and Switzerland have adopted a unique system. They have a board or bureau of plant management, associated very often with a university or sometimes with a board of trade or manufacturing association. Sometimes, too, they are private corporations, but the private corporations are dying out, because working more for their own benefit than for the benefit of the plants. These boards furnish expert advice and the best of instructions such as for the purchasing of supplies. Such matters, handled on a large scale, commend the services of a competent man who could not work for any one concern individually, because it could not afford to pay the price. On such a basis of community work and service, remarkable results have been accomplished.

Mr. Kendall: In my own problem, three of those plants are fairly satisfactory as to the planning departments, but the power end has never been tied into the planning-room work. This exists primarily for the maintenance of the machinery of the plant, the manufacturing machinery and the product. I understand that you, in the first place, would tie all of that control of steam plant right into the general planning room of the manufacturing end of it.

Mr. Polakov: Yes.

Mr. Kendall: Secondly, you spoke about boiler room management associations. Is there any such association existing in this country at the present time?

Mr. Polakov: I do not know of any.

Mr. Kendall: Is this kind of service anything which could possibly be linked up with the technical institutes in their efforts to reach out into wider kind of work? I ask this because the Massachusetts Institute of Technology with its enlarged equipment has recently decided to carry on more or less extensive work through students and faculty in different industries. They are picking out two or three industries in which to begin. I do not know whether they have considered doing this, but is it an absurd thought that perhaps in connection with that kind of work, the technical institutes of the country might inaugurate it for the use of the students and faculty and give that service to the manufacturers of the country? Could not some joint cooperative effort be worked out on these lines?

Mr. Polakov: I feel that it can, with the probable exception of the last thought. Whether it will be as beneficial to the manufacturer or not, it will undoubtedly be beneficial to the student and to the institution, because it will afford the opportunity for the student to get experience and for the professors to get in touch with actual life. But for the manufacturers to have experiments made by men who are nothing but experimenters might be all right and might not be. I should say it is entirely a question of personnel.

Mr. Carl G. Barth:[2] I have during the past few years had the peculiar experience of finding the power departments of two large works too well managed when considered in relation to the rest of the works, both of which have large machine shops.

In both instances there were originally direct current systems of electric power distribution, which later were almost entirely changed over to alternating current systems; and this because the otherwise excellent managers of the respective power departments lacked the necessary experience with machine tools, to handle properly all the problems involved.

---

[1] Norwood, Mass.

[2] Consulting Engineer, Philadelphia, Pa.

All they saw was the cost of the horsepower hour, and having no one to enlighten them they lost sight of the flexibility of direct current motors in connection with machines that must be provided with a range of speeds, the advantages of which flexibility greatly outweigh the difference in the mere cost of the power utilized, which at any rate in most instances constitutes but a small portion of the total cost of any job done in a machine shop.

In large shops both systems should be used, side by side, but for small shops this would not pay, and the direct system is as yet the only one to consider.

And now regarding Mr. Kendall's question,—the power plant he has in mind may be so small that the cost of establishing a Polakov efficiency system in it might not at all be a paying investment when it comes to showing it up in cold-blooded figures of dollars and cents. However, I believe that nobody has a moral right to run a shop and allow any man to work inefficiently in it; it can be prevented. An inefficient man is only partly a man; and it should be our aim, as Mr. Taylor so often said, to help a poor man to become a good man, and a good man to become a better man.

In the directors' room of a large company with which I have recently become connected, there hangs a picture of a late high official, under which was printed his motto, which was, "I would rather make men than money." If Mr. Kendall looks upon business and life as did that man, he will increase the efficiency of his little power plant, regardless of other considerations, if within his possibility to do so.

Mr. Wm. Kent:[1] I believe that there is the greatest encouragement for the Institute of Technology or any similar institution to take up the question of the power plants. It is one of the most used things in the whole shop, and one of the easiest things if you know how to do it. We are now provided with measuring instruments of all kinds. We can have a daily record of coal, and we have from our steam meters knowledge of how much steam is being made; electric meters by which we know how much electricity is being generated. The first thing to do is to get a correct system of accounts in the power plant to know what is being done.

Several years ago the late Edwin Atkinson formed a boiler insurance company. He thought that he would investigate all things about boilers so as to give that information out to the insurers. He sent Mr. Robert S. Hale, of Boston, to Europe to get the best information—he thought he would get better information there—to find out what the European practice was. Mr. Hale came to see me about it, what he should look for there, and what inquiries to make, whom he should see. I told him the best power plant information could be obtained right within one hundred miles of Boston, that he could find nothing in Europe better than the best work of New England.

At that time I was on a commission of three engineers to investigate all of the power plants between Worcester and Pawtucket and the Black Stone River, growing out of a damage suit. We had to find the cost of the power in woolen and other mills, paper mills and so forth. We found that the cost of power varied from twenty dollars per one hundred horse power to over one hundred dollars generally in the Massachusetts plants. Those that had three thousand horse power and were getting power for twenty dollars were as fine as could be found anywhere. The one hundred dollar power plants, were little plants that it would scarcely pay to make improvements in, because the total cost of the power per year was so small that it would scarcely pay to improve the practice . So that the general practice in the work in the past was not so very bad. But the power plant to-day is a simple proposition if you only measure the coal, water, current and steam and have it properly tabulated and charted and have intelligent engineers to report what ought to be done. The institutes can take up that matter very easily if they will.

The first thing for the scientific management engineer to do in regard to the power plant is to get from the statistics the total annual cost of the power plant compared with the total annual cost of everything else. In a great many plants it will be found that notwithstanding bad management of all classes of power plants, it costs such a small part of the total expenditures for the year that it will pay better to make improvements in other directions. I agree with Mr. Barth that in a machine shop power costs so little that it does not amount to much.

Mr. S. E. Whitaker:[1] In regard to the diagrams and charts presented here, they contain a great deal of valuable information. There are one or two questions I would like to ask Mr. Polakov, which did not seem to have been brought out. What is the extent of the savings through the application of these principles to a power plant? In an industrial concern the power plant costs perhaps three per cent or four per cent of the total expense of the product. The saving must be considerable to make it of interest in manufacturing, to any manufacturer. Yet in the power plant of about four hundred or five hundred horse power the total cost of coal in the course of a year is considerable. When it comes to paying the coal bills the manufacturer will be interested to reduce that cost, the annual cost of coal. The electrical companies will supply current in kilowatts of power to an industrial company at about 1.8 or 1.7 cents, the more recent rate. Another question I would like to ask Mr. Polakov is, how low can the cost per kilowatt hour be brought for a small industrial plant through the application of these principles?

Mr. Polakov: In regard to the small cost or small savings, I will say: yes, the percentage is small. Perhaps when we save fifty per cent of the cost of operation of our power plant, that will amount to one-tenth of one per cent of our cost of product. In a talk with a manufacturer along the same line, he said, "I can raise the price without any difficulty three times as much." That is the case and that is the unfortunate part of it. Our industrial structure is wrong, and as I heard a speaker yesterday say, the roof has fallen. I believe that the roof has fallen and that the European War shook it to pieces right over the U. S. A.

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[1] Consulting Engineer, Montclair, N. J.

[1] Consulting Engineer, Boston, Mass.